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CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAI--ETC F/G 13/11
INVESTIGATION OF PLASTIC PIPE FOR USE BY THE CORPS OF ENGINEERS--ETC(U).
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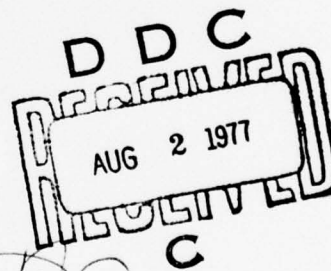
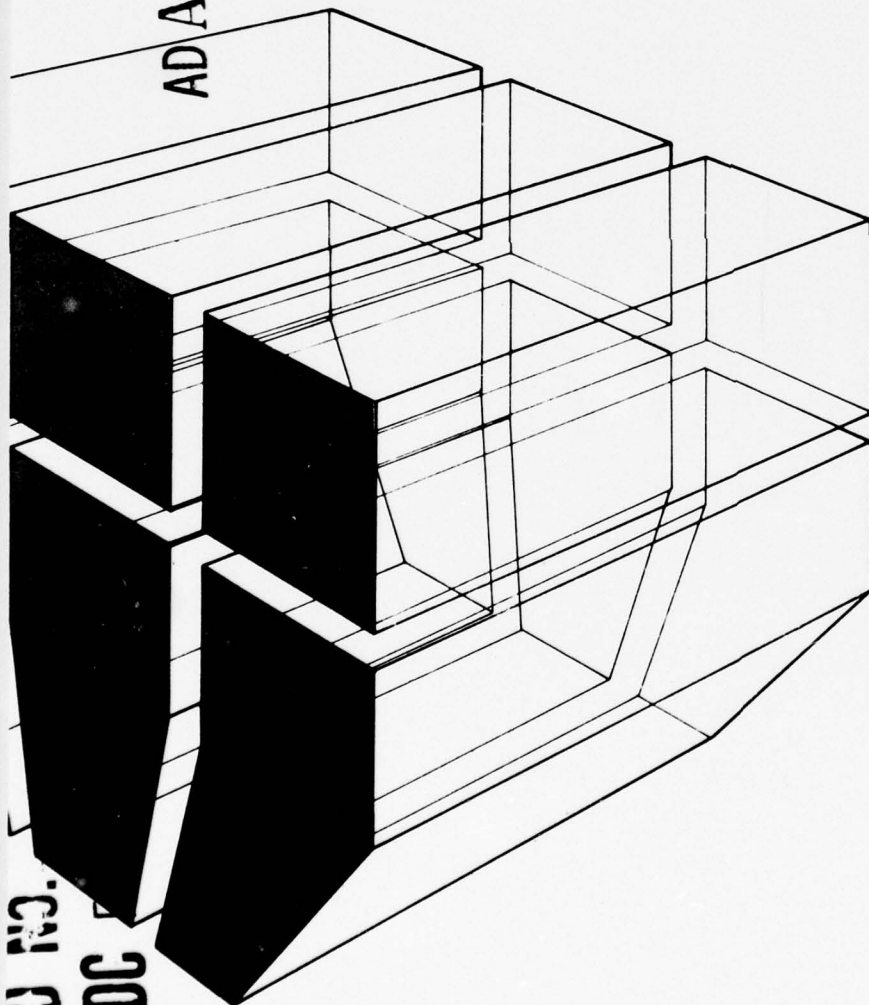
TECHNICAL REPORT M-219
July 1977
Field Jointing of Plastic Pipe

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INVESTIGATION OF PLASTIC PIPE
FOR USE BY THE CORPS OF ENGINEERS

AD A 042313

by
Alvin Smith



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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (4) CERL-TR-M-219	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) INVESTIGATION OF PLASTIC PIPE FOR USE BY THE CORPS OF ENGINEERS.	5. TYPE OF REPORT & PERIOD COVERED (9) FINAL rept. 2	
7. AUTHOR(s) (10) Alvin Smith	6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005 Champaign, IL 61820	8. CONTRACT OR GRANT NUMBER(s)	
11. CONTROLLING OFFICE NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) 4A762731AT41-T7-008 (19217)	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	12. REPORT DATE (11) Jul 1977	
	13. NUMBER OF PAGES (12) 43 p.	
	15. SECURITY CLASS. (of this report) Unclassified	
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are obtainable from National Technical Information Service Springfield, VA 22151		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) drain-waste-vent plastic pipe water hammer tests		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the findings of a study of commercially available plastic pipe used for water distribution, plumbing, drain-waste-vent (DWV), and sewage systems. The study included a survey of military and civilian users of plastic pipe to determine acceptance, a review of model building codes and standards, and a testing program involving the making of joints under different conditions, chemical and mechanical cleaning of DWV piping, and water hammer tests of plastic pipe plumbing. — next page		

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Block 20 continued.

cont. → Results of the study indicate that plastic pipe is an acceptable substitute for metallic pipe in many applications and should be used whenever possible.



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FOREWORD

This research was conducted for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A762731AT41, "Design, Construction, and Operation and Maintenance Technology for Military Facilities"; Task T7, "Materials Research and Development for Military Construction"; Work Unit 008, "Field Jointing of Plastic Pipe." The applicable QCR is 1.02.001(2). The OCE Technical Monitor for the study is Mr. Harold McCauley.

The work was performed by the Construction Materials Branch (MSC), Materials and Science Division (MS), U. S. Army Construction Engineering Research Laboratory (CERL), Champaign, IL. Dr. G. R. Williamson is Chief of MS, and Mr. P. A. Howdysell is Chief of MSC.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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INVESTIGATION OF PLASTIC PIPE FOR USE BY THE CORPS OF ENGINEERS

1 INTRODUCTION

Background

Although plastic pipe has been commercially available since the late 1930s, thoroughly engineered and tested plastic pipe has only been available for 15 to 20 years. Failure of numerous plastic pipe systems installed prior to that period prompted much closer scrutiny of the manufacture and installation of plastic pipe. The result of this scrutiny has been a great increase in the acceptance of plastic pipe in many applications previously reserved for traditional metallic, cementitious, and clay pipes.

Presently, over 1 billion lb (450 million kg)¹ of various plastics are converted annually into high-quality, dependable pipe and fitting products which are gaining or have gained acceptance as alternate materials by virtually every major model building code authority in the United States. As local building code authorities have followed the model building codes, contractors have been able to save many millions of dollars for water distribution districts, sewage systems, and homeowners.² These savings have prompted interest in the use of plastic pipe by the Corps of Engineers.

Purpose

The purpose of this study was to gather data for the Office of the Chief of Engineers (OCE) to use in deciding whether to allow or restrict the use of plastic pipe in military construction and rehabilitation projects.

Approach

Thermoplastic pipe in sizes normally used for plumbing, drain-waste-vent (DWV), and sewer systems, as well as pipe sizes typically used for water distribution systems (which were reviewed but not evaluated) were studied in a series of steps. Existing information, model codes, and specifications were reviewed to obtain data on the types of plastic pipe and their applications, and the types of joining techniques. After this review,

joints made under various conditions and joints of dissimilar materials were laboratory tested. Mechanical and chemical cleaning tests of laboratory-fabricated DWV pipe, and water hammer tests of plastic pipe plumbing were also conducted. Military and civilian users were surveyed to assess the performance of plastic pipe in use. A plastic pipe selection guide was then prepared, and Corps of Engineers guide specifications were reviewed to determine which might require modification if use of plastic pipe is authorized.

Scope

This study covered thermoplastic pipes only. Thermoset plastic pipes were not studied, although many of the criteria given apply to them as well. The pipe materials themselves were not studied in depth, since they were already well identified by American Society for Testing and Materials (ASTM) and other standards.

Several unanswered questions regarding plastic pipe were not addressed in this study. Work is presently being performed on several of these questions, including (1) whether essential properties will be maintained when the pipe is exposed to internal pressure, chemical corrosives, and thermal changes; (2) the pipe's stability when subjected to stresses caused by the flow of hot and cold water; and (3) the aging effects, hydraulic efficiency, acoustical qualities, flammability, and related phenomena.

Mode of Technology Transfer

The results of the investigations documented in this report are being incorporated in a draft Technical Manual (TM) dealing with plastic pipe system design and installation which is currently being prepared. This TM will provide design engineers with a means of selecting the correct plastic pipe system for an application and will detail sufficient design features to direct proper installation. In addition, the results of this study may impact a number of Corps of Engineers guide specifications, as discussed in Chapter 5.

2 PLASTIC PIPE: TYPES, APPLICATIONS, JOINING, AND STANDARDS

Types of Plastic Pipe and Their Applications

Plastic pipe can be divided into two main groups—thermoplastic and thermoset. Thermoplastic materials are those which can be softened by adding heat, and then reshaped, usually a great many times if desired.

¹ *Facts and Figures of the Plastics Industry* (Society of the Plastics Industry, Inc., August 1975).

² D. A. Chasis, *Plastic Piping Systems* (Industrial Press, Inc., 1976), pp 135-155.

Thermosets, on the other hand, cannot be softened by heat once they have "set." Thermoplastics are much more widely used (and in greater amounts) for plastic pipe than are thermosets. In certain applications, however, thermosets are preferred because of their greater resistance to elevated temperatures and their ability to be reinforced with glass fiber to much greater strengths than thermoplastics. Thermoset plastic pipe was not included in this study.

Most thermoplastic materials can be molded into pipe or tube configurations. Special properties of specific materials make them particularly suitable for use in special applications such as corrosive fluid drains, etc. However, relatively few plastics have high volume production and widespread use. The most important ones are polyvinyl chloride, acrylonitrile-butadiene-styrene, and polyethylene.

Polyvinyl chloride (PVC) is produced by controlled polymerization of vinyl chloride monomer. The conditions of polymerization and subsequent compounding with additives create several types and grades of PVC. PVC pipe, which is non-flammable and can be used in many applications, accounts for about two-thirds of all thermoplastic pipe used (on a weight basis). PVC is available in various types, sizes (1/2 through 16 in. [13 through 466 mm] diameters), and pressure ratings for water distribution (up to about 120°F [49°C]) and DWV uses. ASTM and the National Sanitation Foundation (NSF) publish standards and specifications for material, design, and installation of PVC pipe. Several available means of joining PVC are discussed in the next section.

Acrylonitrile-butadiene-styrene (ABS) plastic is made by copolymerizing the three constituents in about 15:6:79 (A:B:S) proportions. ABS is used extensively in DWV and sewer applications. It is somewhat more expensive than PVC and accounts for less than 10 percent (by weight) of plastic pipe used. It is not as strong as PVC, but has better impact resistance. ABS is available in schedule 40 Iron Pipe Size (IPS) and SDR* in diameters from 1/2 through 6 in. (13 through 152 mm), and is covered in ASTM and NSF standards and specifications. Joints are usually solvent cement.

Polyethylene (PE) is polymerized ethylene. Although not as strong as PVC or ABS, it has excellent chemical

resistance. PE represents about 15 percent (by weight) of plastic pipe used. PE pipe is most often used in water and gas distribution; it is considered satisfactory for water up to about 80°F (27°C) and for natural, manufactured, and mixed gases. Since the material can be made in many densities, each having a peculiar set of properties, matching the material and design carefully is important. PE pipe is available in many sizes of long length coils (1/2 to 2 in. [13 to 51 mm] diameter) and as rigid pipe (3 to 48 in. [76 mm to 1.2 m] diameter). Very large diameter PE pipe is usually used to repair existing sewer pipe by inserting it in the deteriorated or faulty lines. ASTM, NSF, and the American Gas Association (AGA) have specifications and standards applicable to PE pipe. Joining of PE pipe is discussed in the next section.

Other types of plastic pipe account for the remaining 10 percent (by weight) of pipe used. They include chlorinated polyvinyl chloride, polypropylene and polybutylene.

Chlorinated polyvinyl chloride (CPVC) is made by chlorinating (introducing more chlorine into) PVC. CPVC has many properties very similar to those of PVC, but has a higher temperature resistance; it can withstand about 200°F (93°C) temperatures. It is therefore most typically used in hot fluid distribution. It is available in 1/2 through 6 in. (13 through 152 mm) diameters. ASTM and NSF have standards on CPVC material and pipe. CPVC pipe is usually joined by solvent cementing, which is discussed in the next section.

Polypropylene (PP), which is prepared by polymerizing propylene, is very chemical-resistant and lightweight. It is predominantly used for low pressure and acid waste lines. ASTM has a standard for one pressure-rated PP pipe, which must be schedule 80 IPS, and another standard for low pressure PP pipe (schedule 40 IPS). PP is available in 1/2 through 8 in. (13 through 203 mm) diameters, and is joined by fusion methods, which are discussed in the next section.

Polybutylene (PB) is made by polymerizing butene-1. It is quite similar to PE pipe but is more creep- and abrasion-resistant and can withstand higher temperatures. Like PE, it is used mostly in gas and water distribution. PB pipe is available in 1/4 through 12 in. (6 through 305 mm) diameters. It is covered by ASTM and NSF standards and is joined in much the same way as PE. In addition, flared joints can be used with PB in much the same way as with copper tubing.

*SDR = Standard Dimension Ratio, which is determined by dividing the outside diameter of the pipe by its wall thickness.

The size and pressure rating ranges found to be available for these six types of plastic pipe appear to meet most of the needs of water and gas distribution, electrical conduit, DWV, and sewer systems.

Numerous other thermoplastic resins are used in forming pipe and tubing. Materials such as polyvinylidene chloride (Saran), polyvinylidene fluoride (Kynar), polytetrafluorethylene (Teflon), cellulose acetate butyrate styrene rubber, and many others find application in such areas as metal pipe and valve linings or in specialty uses in the chemical processing areas. Manufacturers can provide information on these specialty pipes.

The many kinds of plastic pipe demand extra care in designing and installing systems using plastic pipe. Kinds and grades of plastic pipe cannot be indiscriminately mixed in a single system.

Joining Plastic Pipe

The methods of joining which can be used with plastic pipe include solvent cementing, threading, butt heat fusion, electrical resistance, flanging, socket heat fusion, grooving, compression inert, O-ring joints, and cold-flared compression fittings. However, no single method can be used with all the materials discussed. Satisfactory installation of plastic pipe requires that the proper method of joining be selected and properly used. The pipe manufacturer can recommend the proper method for a particular application. Often the manufacturer will reference an ASTM procedure as applicable. Table 1 gives the methods of joining, the types of pipe with which they should be used, and their advantages and disadvantages. This information was adapted from numerous sources including books and manufacturers' literature, and represents present practice with the more commonly used kinds of plastic pipes.

As with conventional pipe materials, certain things must be done prior to making the joint. The pipe should be inspected carefully for foreign material and damage. If the pipe is in satisfactory condition, any required cuts should be made, followed by cleaning any cuttings and burrs from the pipe. Special cutting tools for plastic pipe should be used. Most of these cutters, which work very well, resemble copper tubing cutters. The pipe should be cut square, and the edges slightly beveled to facilitate inserting the end into fittings.

If a special cutter is not available, a fine-toothed saw and miter box on jig fixture should be used. If a saw is used for cutting, burr removal and beveling should be done before forming the joint.

After cutting is completed, the cut area should be reinspected for flaws or damage. The pipe and fitting should always be cleaned with sandpaper or a clean cloth and an approved cleaner before the joint is made.

Plastic Pipe Standards and Specifications

To assure high quality products and adequate design criteria for plastic pipe, numerous organizations have generated standards, specifications, and other regulating constraints. These constraints help producers maintain a desired quality product and assure consumers (designers) that the product will perform as advertised.

Some of the prominent types of standards and specifications and their proponent organizations are listed below.

- a. American Society for Testing and Materials (ASTM) studies and prepares widely accepted standard test methods for materials, procedures, and processes.
- b. Federal Specifications (FED-SPEC) are prepared and maintained to cover goods and services procured by the General Services Administration of the U. S. Government.
- c. Military Specifications (MIL-SPEC) and Standards (MS), which are prepared by the Department of Defense, generally cover materials intended for military applications.
- d. The National Bureau of Standards (NBS) prepares Product Standards (PS), which are guidelines for producers to voluntarily follow. PSs are usually matched by ASTM and other standards.
- e. The Federal Housing Administration (FHA) of the Department of Housing and Urban Development (HUD) issues standards applicable to the housing industry.
- f. The American National Standards Institute (ANSI) has classified plastic pipe standards in the B72 and K65 series. Each standard presently cataloged by ANSI is also covered by an identical ASTM standard.
- g. The National Sanitation Foundation (NSF) Testing Laboratory tests and evaluates equipment and products for compliance to NSF standards. The Testing Laboratory has issued the NSF Seal of Approval to

cover plastic materials, pipe, fittings, and appurtenances for both potable water and DWV systems. The use of the seal implies that the producer has agreed to allow NSF to visit, inspect, and test products bearing the seal at unannounced times. Samples may be selected at the production site, from warehouse stocks, or at the installation site. Such a program encourages producers and distributors to maintain products at an acceptable quality.

h. Commercial Standards (CS) (which reference ASTM procedures) are standards voluntarily assumed by individual manufacturers' associations.

i. The International Association of Plumbing and Mechanical Officials (IAPMO) publishes standards.

j. Canadian Standards Association (CSA) publishes standards and recommended practices.

Table 1
Methods of Joining

Method	Pipe Materials	Disadvantages	Advantages
Solvent-cementing	PVC, ABS, CPVC	Cannot be done properly under adverse conditions;* requires waiting to test joint; leaks difficult to repair; joint is permanent.	Quick, easy; joint is strong; no special tools required.
Threading	All (schedule 80 and over)	Possible to over-torque joint; reduces pressure rating; requires special tools for threading.	Can prefabricate; leaks easy to repair; joint can be tested immediately.
Butt heat fusion	PE, PP, PB	Requires special tools; hard to do in cold weather; joint is permanent.	Very strong joint; joint can be tested almost immediately; can be used with large diameter pipe.
Electrical resistance	PP	Requires expensive tooling; electrical source needed; coil may come in contact with fluid in line.	Quick; leaks easy to repair.
Flanging	All	High initial cost and labor; limited to about 150 psi (1000 kPa)	Essentially same as threaded.
Socket heat fusion	PE, PP, PB	Same as butt heat fusion.	Same as butt heat fusion.
Grooving	All	Requires expensive tools; couplings expensive; reduces pressure rating.	Can prefabricate; easy to assemble and disassemble; can be tested immediately.
Compression insert	PC, PB	Limited to about 3 in. (76 mm) diameter; reduces flow capacity of system.	Easy to install; no special tools required; leaks easy to repair.
O ₂ Ring	PVC	Not recommended for fluids other than water and sewage; thrust blocking required; should not be used above ground.	Easy to install in all weather; no special tools required; joint can be tested immediately; high pressure ratings; expansion and contraction of system.

*Adverse conditions are considered to be temperatures outside the range of 40° to 90°F (4° to 32°C), wetness, direct sun exposure, or winds of 15 mph (24 km/hr) or higher.

k. The Plastic Pipe Institute (PPI) of the Society of the Plastics Industry publishes numerous documents which contain valuable design and practice techniques related to plastic pipe.

l. American Water Works Association (AWWA) publishes standards pertaining to water distribution.

m. American Gas Association (AGA) maintains standards relating to gas transmission (both natural and manufactured).

Appendix A lists the standards groups and the number and title of their published standards pertaining to thermoplastic pipe.

Acceptance by Codes

NBS recently reviewed the status of code approvals and restrictions on the use of thermoplastic piping.³ Results indicated that code authorities have not generally accepted thermoplastic piping for use in residential plumbing systems because it was unproven, while metallic piping was already acceptable and available. In the past few years, however, accumulation of a body of supporting data has resulted in acceptance of the material for certain applications. For DWV systems, NBS reported that a recent survey found that ABS and PVC is now permitted for single-family housing construction by more than 86 percent of local codes in the United States compared to 77 percent in 1972, 71 percent in 1971, 50 percent in 1970, and 25 percent in 1969. In addition, NBS reported that ABS and/or PVC are now permitted by 70 percent of local codes for DWV in low-rise apartments, and by 49 percent for use in high-rise structures.

The increase in the number of local approvals of plastic pipe reflects the changes being made in the model codes upon which many local codes are based. NBS reported that of 2250 code authorities asked to indicate whether their plumbing code was based on or identical with any of the model codes, 30 percent indicated that their codes were based on the National Standard Plumbing Code, 22 percent on the Uniform Plumbing Code, 17 percent on the Southern Standard Plumbing Code, and 15 percent on the Basic Plumbing Code. As the NBS findings summarized in Appendix B

show, these four codes, as well as the Canadian Plumbing Code, list plastic pipe as an allowable alternate material.

The information in Appendix B also indicates that acceptance by code authorities of thermoplastic piping for water supply is more limited than for DWV piping. NBS reported that where allowed within the building, use is for the most part restricted to CPVC; when allowed underground, outside the building line, PE is frequently used.

A review of the NBS survey suggests that DWV represents the largest use (in pounds) of plastic pipe. This conclusion is misleading, however, as indicated by Table 2. On the basis of numbers of users, the NBS

Table 2
Quantities of Thermoplastic Pipe by Kind of Pipe and Type of Application (1974)*

	Pipe Used, million lb (million kg)
Pressure	663.6 (301.0)
PVC	555.7 (252.1)
PE	103.0 (46.7)
Other	4.9 (2.2)
DWV	226.4 (102.7)
PVC	119.2 (54.1)
ABS	107.2 (48.6)
Conduit	275.9 (125.1)
PVC	275.9 (125.1)
Sewer & Drain	258.0 (117.0)
PVC	107.0 (48.5)
PE	106.0 (48.1)
Styrene Rubber	45.0 (20.4)
Other	30.1 (13.7)
PVC	8.1 (3.7)
PE	8.0 (3.6)
ABS	12.8 (5.8)
Other	1.2 (0.5)
Total	1,454.0 (659.5)
PVC	1,065.9 (483.1)
PE	217.0 (98.4)
ABS	120.0 (54.4)
Styrene Rubber	45.0 (20.4)
Other	6.1 (2.8)

*Adapted from *Facts and Figures of the Plastics Industry* (Society of the Plastics Industry, Inc., August 1975).

³R. S. Wyly, et al., *Review of Standards and Other Information on Thermoplastic Piping in Residential Plumbing*, Building Science Series 68 (National Bureau of Standards, May 1975).

survey is correct, but it is incorrect in terms of pounds (and feet) of plastic pipe used. As the table shows, nearly 50 percent of the 1.5 billion lb (680 million kg) of resins converted into plastic pipe in 1974 were converted into pressure piping, while DWV pipe represented only about 15 percent of the total.

The growth rate shown for 1970 through 1974 (Table 3) indicates that use of plastic pipe is increasing sharply. It is anticipated that municipal codes will generally accept plastic piping as more successful experience data are accumulated.

3 DISCUSSION OF USER SURVEY AND LABORATORY TESTS

Survey of Military and Civilian Users

To assess the performance of plastic pipe in use, 26 attendees of a Facilities Engineering Corrosion Course held at the U. S. Army Construction Engineering Research Laboratory (CERL) were questioned about the use of plastic pipe at their Army facilities. Virtually all geographical sections of the contiguous United States were represented. Appendix C contains the ques-

Table 3
Growth Trends in the Use of Thermoplastic Pipe
By Kind of Pipe and Type of Application*

Year	Kind of Pipe, million lb (million kg)				Total
	PVC	ABS	PE	Other	
1970	387 (176)	84 (38)	82 (37)	84 (38)	637 (289)
1971	551 (250)	113 (51)	113 (51)	104 (47)	881 (400)
1972	877 (398)	164 (74)	180 (82)	109 (49)	1,330 (603)
1973	1,131 (513)	167 (76)	190 (86)	99 (45)	1,587 (720)
1974**	1,066 (484)	120 (54)	217 (98)	51 (23)	1,454 (669)
Growth Rate					
1970-1974	29.0%	9.3%	28.0%	-13.0%	23.0%
Year	Type of Application, million lb (million kg)				Total
	Pressure	Conduit	DWV	Other	
1970	357 (162)	102 (46)	60 (27)	118 (54)	637 (289)
1971	476 (216)	128 (58)	120 (54)	157 (71)	881 (400)
1972	669 (303)	213 (97)	218 (99)	230 (104)	1,330 (603)
1973	724 (328)	350 (159)	238 (108)	275 (125)	1,587 (720)
1974**	663 (301)	276 (125)	213 (97)	168 (76)	1,320 (599)
Growth Rate					
1970-1974	16.7%	28.0%	37.0%	9.2%	20.0%

*Compiled from recent issues of various trade journals.

**Total construction in terms of constant dollars declined severely in 1974.

tionnaire used and a summary of the 12 written and 14 oral responses. Only two of the 26 respondents indicated that no plastic pipe had been used at their facilities. Most experiences with plastic pipe had been good.

The amount of pipe used ranged from a few hundred feet to several miles. Principal uses indicated were for branch water lines, DWV, sewer lines, irrigation, and electrical line conduits. The few failures experienced had been determined to result from improper installation or inadvertent overloading of entrenched lines.

Appendix C also summarizes the responses of eight civilian users—engineering firms and contractors engaged in the design and installation of plastic pipe—who were surveyed. Experience in plastic pipe systems ranged from 3 to 13 years. Types of installations were primarily water distribution, plumbing, DWV, and sewer collection systems. All experiences with plastic pipe had been good, particularly in the past few years. One firm had installed more than 1000 miles (1600 km) of 2 to 12 in. (51 to 305 mm) diameter water distribution lines in rural areas. These installations were in hilly terrain with most common soil types represented. No crushing or leaking problems had occurred in any of the lines.

The results of the military and civilian user surveys indicate satisfactory performance and acceptance of plastic pipe in a variety of applications.

Joint Tests

Joints were made with various kinds of plastic pipe under a variety of conditions in the laboratory. All common types of joints were made—straight coupling, Ys, Ls, and Ts. The methods used were solvent cementing, threading, and compression insert. These methods were selected as most applicable to the kinds and sizes of pipe used in the study. Table 4 summarizes the joint tests and results. ASTM procedures were used in forming the solvent-cemented joints (D 2855-73). Manufacturers' directions for use of the solvent cements were followed, where applicable.

PVC, ABS, and CPVC pipes of schedule 40 IPS were used in forming solvent-cemented joints. Only PVC (schedule 80 IPS) was used for threaded joint studies. Both 100-psi (690-kPa) PE and PB were used in forming compression insert joints. Pipe diameters ranged from 1/2 to 4 in. (13 to 102 mm).

Temperatures used in the study ranged from 25° to 110°F (-4° to 43°C).

Although none of the joint types presented a special problem, it was found that care must be exercised to form good joints of any kind. A brief familiarization period, followed by some practice, appears to be sufficient to assure good joints.

The solvent-cemented joints required extra care at both temperature extremes: at the low temperature, the joint was allowed a minimum of 2 hours to "set"; at the high temperature, solvent in the solvent cement evaporated rapidly, requiring assembly to be fast. Threaded and compression insert joints were both formed easily within the temperature range used.

For the smaller pipe diameters (2 in. [51 mm] or less), one person could perform the joining with ease. Above 2 in. (51 mm) in diameter, two people were required.

In some cases, faulty joints were made intentionally. Following leak testing, repairs were made. Threaded and compression insert joints were repaired easily and quickly by tightening the joint or compression band. The leaky solvent-cemented joints were very difficult to repair, and success of the repairs was questionable. In such cases, cutting out the faulty joint and fitting a new short section of pipe (with fittings) into the line would appear to be more appropriate.

Dissimilar materials were joined using solvent cement in the second phase of the joint tests. Results indicated that PVC and CPVC can be joined, provided CPVC cement is used. PVC and ABS are difficult to join and should therefore not be joined or intermixed within a system. Because of the differences in the materials' thermal expansion, only approved adapters should be used for interconnecting different nonmetallic pipe materials or metallic and nonmetallic connections. PVC and PE, CPVC and PE, and ABS and PE cannot be joined, since one type requires solvent welding and the other requires compression inserts.

Since the cost of a field study large enough to be conclusive was prohibitive, the experiences of the engineering and construction firms surveyed were used to assess field condition joining. Outside installation (water distribution and sewer lines) had been performed in subfreezing temperatures in a number of cases. The engineers and contractors interviewed indicated that O-ring/socket joints presented no problem, but that solvent-cemented joints required a long time (hours) prior to filling, testing, and backfilling operations, as recommended in ASTM D 2855-73. For inside instal-

Table 4
Summary of Joint Tests
(SI Conversion Factors: 1 in. = 25.4 mm; °F = 32 + 5/9 °C)

Pipe Material	Pipe Size	Wall Thickness	Number of Joints Made	Joining Method	Basis of Joining Method Selection	Joining Conditions	Test	Remarks
PVC	3/4 in.	SCH 40	64	Solvent Cement	ASTM, Manufacturer Recom. Economy	25°F	Visual; Pressure*(1)	Fast, Easy to Learn, Reliable
PVC	3/4 in.	SCH 40	64	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure(1)	Fast, Easy to Learn, Reliable
PVC	3/4 in.	SCH 40	64	Solvent Cement	ASTM, Manufacturer Recom. Economy	115°F	Visual; Pressure(1)	Fast, Easy to Learn, Reliable
PVC	1 1/2 in.	SCH 40	60	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
PVC	1 1/2 in.	SCH 40	27	Threaded	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
PVC	3 in.	SCH 40	36	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
PVC	3 in.	SCH 40	20	Threaded	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
PVC	4 in.	SCH 40	20	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
PVC	4 in.	SCH 40	10	Threaded	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
CPVC	3/4 in.	SCH 40	64	Solvent Cement	ASTM, Manufacturer Recom. Economy	25°F	Visual; Pressure(1)	Fast, Easy to Learn, Reliable
CPVC	3/4 in.	SCH 40	64	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure(1)	Fast, Easy to Learn, Reliable
CPVC	3/4 in.	SCH 40	64	Solvent Cement	ASTM, Manufacturer Recom. Economy	115°F	Visual; Pressure(1)	Fast, Easy to Learn, Reliable
CPVC	1 1/2 in.	SCH 40	52	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
ABS	1 1/2 in.	SCH 40	60	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
ABS	1 1/2 in.	SCH 40	27	Threaded	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
ABS	3 in.	SCH 40	36	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable

*Pressure tests included:

- (a) filling the line with water, applying 10 psi pressure and observing for leaks for one hour;
- (b) increasing internal pressure to 50 psi and holding for 12 hours; and
- (c) increasing internal pressure to 90 psi and holding for 4 hours minimum.

(1) Also subjected to water hammer test.

Table 4 (cont'd)
Summary of Joint Tests
(SI Conversion Factors: 1 in. = 25.4 mm; °F = 32 + 5/9 × °C)

Pipe Material	Pipe Size	Wall Thickness	Number of Joints Made	Joining Method	Basis of Joining Method Selection	Joining Conditions	Test	Remarks
ABS	3 in.	SCH 40	20	Threaded	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
ABS	4 in.	SCH 40	20	Solvent Cement	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
ABS	4 in.	SCH 40	10	Threaded	ASTM, Manufacturer Recom. Economy	70°F	Visual; Pressure	Fast, Easy to Learn, Reliable
PE	1 1/2 in.	SDR 15	64	Compression Insert	Manufacturer Recom.	70°F	Visual; Pressure	Fast; Easy
PE	1 in.	SDR 15	50	Compression Insert	Manufacturer Recom.	25°F	Visual; Pressure ⁽¹⁾	Fast; Easy
PE	1 in.	SDR 15	50	Compression Insert	Manufacturer Recom.	115°F	Visual; Pressure ⁽¹⁾	Fast; Easy
PB	3/4 in.	SDR 15	64	Compression Insert	Manufacturer Recom.	70°F	Visual; Pressure ⁽¹⁾	Fast; Easy
PB	3/4 in.	SDR 15	50	Compression Insert	Manufacturer Recom.	25°F	Visual; Pressure ⁽¹⁾	Fast; Easy
PB	3/4 in.	SDR 15	50	Compression Insert	Manufacturer Recom.	115°F	Visual; Pressure ⁽¹⁾	Fast; Easy

(1) Also subjected to water hammer test.

lations (plumbing and DWV), solvent-cemented jointing was the primary method used. Since inside work generally is dry and, in many cases, done at somewhat higher temperatures, no problems with this type of joint were reported. Allowing the necessary set time for the joints before filling and testing was required, however.

Elevated-temperature installation of solvent-cemented joints required that cement be protected from direct exposure to sunlight and that cement cans be closed except when in actual use. It is a standard policy among the installers interviewed to dispose of cement when it begins to thicken or become stringy. Until that condition exists, the cements apparently work satisfactorily. No quality control measure is used other than the experienced installer's recognition of the cement's condition.

The joining tests and interviews with experienced contractors indicated that good serviceable joints can be made by proper use of presently available methods.

Personnel who are to do the joining should be trained by someone familiar with the requirements. For more unusual methods such as butt fusion, socket heat fusion, or electrical resistance, specialized training should be required, in much the same way that welders joining steel pipe are required to be certified welders.

Cleaning of Plastic Pipe DWV Systems

Model DWV systems of PVC and ABS pipe were fabricated in the laboratory for use in determining the effects of chemical and mechanical cleaning on PVC and ABS pipe used in DWV systems. The models were constructed to represent typical configurations (Figure 1) common in residential and small facilities. The

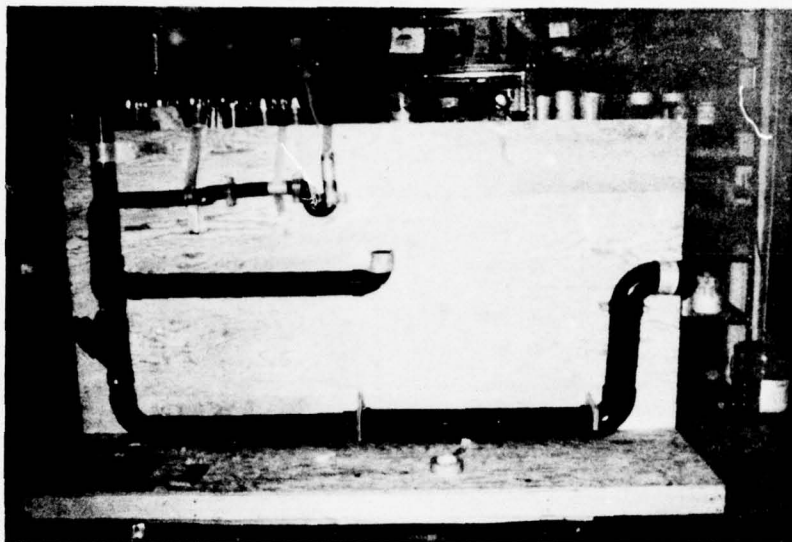


Figure 1. Model DWV system.

models included pipe and fittings from the outlet of a sink or lavatory. All assemblies were joined using the solvent-cementing method.

Chemical Cleaning

The effects of commercial chemical cleaning products on plastic pipe DWV systems were tested. Adding excessive amounts of certain cleaners to small amounts of water standing in a pipe (such as a P-trap) generates a great deal of heat. The resulting temperature rise within the plastic pipe can soften the pipe, causing it to become rubbery and sag between supports. To assess this effect, various proportions of cleaner and water were mixed, and the resulting temperatures noted (Table 5).

Sections of 1 1/2-in. (38-mm) diameter ABS and PVC pipe were then subjected to mixtures of the cleaners and water to determine whether the pipe material could withstand the high temperatures. The only solution causing a problem was Drano and water. When 200 g of Drano were dissolved in 100 g of water, the resulting solution was hot enough (140°F [60°C]) to melt the ABS pipe and to soften the PVC pipe. Dissolving 200 g of Drano in 200 g of water resulted in a temperature (125°F [52°C]) at which both ABS and PVC softened slightly.

The cleaners were then used in 1 1/2-in. (38-mm) drains (which included a P-trap section) of ABS and PVC pipe. The water was introduced into the pipe first, followed by the cleaner. When the directions on the label were followed, no adverse effects were evident. When large quantities of Drano in proportion to the water present were added, both ABS and PVC pipes were softened. However, the joints in pipes maintained their integrity even when efforts were made to pull the pipe out of the fitting. Table 6 summarizes the results. The temperatures were measured on the **outside** of the pipe using a contact pyrometer.

Mechanical Cleaning of DWV Systems

A second method of cleaning obstructions from DWV lines is by mechanical means. A well-designed DWV system provides for access to each straight-run section so that cleaning can be accomplished if necessary.

The most common ways of mechanically cleaning a DWV pipe are "snaking" with a flat steel ribbon through the line, "rodding" with a rigid rod, and using a power-driven rotating toothed cutter to chew obstructions into movable pieces.

Table 5
Temperatures Achieved With Various Proportions of Cleaner and Water

Cleaner	Weight of Cleaner, g	Weight of Water,* g	Maximum Temperature, °F (°C)	Approximate Time to Reach Maximum Temperature, minutes
Drano	50	12.5	284 (140)	3
	50	25	264 (129)	3
	50	50	244 (118)	5
	50	100	217 (103)	5
	50	200	174 (79)	5
Vanish	50	12.5	17 (25)	1
	50	25	75 (24)	1
	50	50	75 (24)	1
	50	100	68 (20)	1
	50	200	63 (17)	1
Sani Flush	50	12.5	88 (31)	1
	50	25	81 (27)	1
	50	50	81 (27)	1
	50	100	72 (22)	1
	50	200	65 (18)	1
Liquid Plumr	50	12.5	73 (23)	5
	50	25	73 (23)	5
	50	50	73 (23)	5
	50	100	73 (23)	5
	50	200	73 (23)	5
Household lye (sodium hydroxide)	50	12.5	136 (58)	10 seconds
	50	25	140 (60)	10 seconds
	50	50	174 (79)	10 seconds
	50	100	153 (67)	1
	50	200	140 (60)	2

*Initial water temperature 52°F (11°C)

Snaking causes no problems with plastic pipe, since it is impossible to inflict enough force through the flexible ribbon to damage the pipe. Rodding should not be done to any type of pipe—plastic or metallic—since the amount of force that can be produced with vigorous pounding could shatter or punch a hole through a fitting. Tests were conducted with a rotating mechanical cleaner to determine if it can be used with plastic pipe. A rotary power-driven cleaner was run through typical DWV system configurations of ABS and PVC pipe for 2 hours; X rays were made at 15-minute intervals. ABS and PVC pipes with known defects (saw marks) were X-rayed for comparison purposes. Very shallow scratches of less than 1/32 in. (0.8 mm) depth were detectable by this means; the location and approximate depth and length of larger defects were easily identified. The X rays of the pipes cleaned with the rotary cleaner

showed minor scratching confined to elbows within the system. The elbows were subsequently cut out of the system and visually examined. The examination confirmed that this type of mechanical cleaning would cause no appreciable damage to a plastic pipe DWV system if the length of time were reasonable. The outward appearance of the model was not changed as a result of the testing.

Water Hammer Tests

Water hammer is a phenomenon which may occur when the flow rate of a liquid (or other fluid) flowing within a pipe changes. When this occurs, the velocity of the fluid also changes, resulting in a pulse wave or surge of pressure along the fluid. The magnitude of the pulse wave may create a shock pulse within the pipe. Under certain conditions, this shock load may be great

Table 6
Chemical Cleaning of DWV Systems

Type of Pipe	Cleaner	Weight of Cleaner, g	Weight of Water, g	Temperature at Lowest Point on P-Trap °F (°C)	Temperature °F (°C)	Approximate Time To Reach Maximum Temperature, minutes	Remarks
PVC 1 1/2 in. pipe Schedule 40	Drano						
	(Direction)	35	336	125 (52)	125 (52)	5	
	(Strongest Solution)	300	150	150 (66)	190 (88)	10	Pipe softened in only a few places.
	Liquid Plumr						
	(Direction)	454	130	80 (27)	80 (27)	30	
	Vanish						
	(Direction)	113	130	71 (22)	71 (22)	20	
	Sani Flush						
	(Direction)	113	130	71 (22)	71 (22)	20	
	Lye						
	(Direction)	35	130	100 (38)	100 (38)	20	
ABS 1 1/2 in. pipe Schedule 40	Drano						
	(Direction)	35	336	124 (52)	140 (60)	5	
	(Strongest Solution)	300	150	140 (60)	180 (82)	10	Pipe softened and distorted.
	Liquid Plumr						
	(Directions)	454	130	80 (27)	80 (27)	30	
	Vanish						
	(Directions)	113	130	73 (23)	73 (23)	20	
	Sani Flush						
	(Directions)	113	130	73 (23)	73 (23)	20	
	Lye						
	(Directions)	35	130	110 (43)	110 (43)	20	

enough to rupture almost any kind of pipe. According to the American Water Works Association (AWWA)⁴ the pressure rise due to water hammer may be calculated by:

$$P_s = \frac{aV}{2.31g} \quad [\text{Eq 1}]$$

and

$$a = \frac{4660}{(1 + KD_i/Et)^{1/2}} \quad [\text{Eq 2}]$$

where a = velocity of pulse wave in feet per second

⁴ Anon., *AWWA Standard for Polyvinyl Chloride (PVC) Pressure Pipe, 4 in. Through 12 in. for Water* (American Water Works Association, 1975), p. 12.

K = bulk modulus of water = 294,000 psi

D_i = inside diameter of pipe in inches

E = modulus of elasticity of pipe material

t = wall thickness of pipe in inches

P_s = pressure rise in pounds per square inch

V = velocity change in feet per second, occurring within the critical time 2L/a where L is the length of the pipe in feet

g = gravitational acceleration, 32.2 feet per second.

There is a limiting factor for valve closing time based on the pipe length and the rate of sound transmission through the fluid. The critical time is given by $T \leq 2L/a$, where T is the valve closure time in seconds, L is the pipe length, and a is the velocity of pulse wave in the fluid.⁵ If the actual time of closure is greater than the critical time, the actual water hammer is reduced approximately in proportion to the ratio of the critical to the actual time of closure.

The following formula allows a quick estimation of the pressure pulse when the factors of velocity, length and time are known:

$$P_p = \frac{0.070 VL}{T} \quad [\text{Eq 3}]$$

where P_p is the pulse pressure in psi

V is velocity in feet per second

L is the pipe length in feet

T is the velocity change mechanism (valve closing time in seconds)

0.070 is the constant.⁶

As can be seen in this relation, a combination of long pipe, high liquid velocity, and short valve closing time can cause extremely high pressure pulses. For example, assuming a 100-ft (30-m) long pipe, a velocity of 10 ft/sec (3 m/sec), and a quick closing valve time of 0.1 sec, the pressure pulse would be

$$P_p = \frac{(0.070)(10)(100)}{0.1}$$

$$P_p = 700 \text{ psi } (4.82 \times 10^3 \text{ kPa}).$$

Plastic pipe systems should be sized such that liquid velocity does not exceed 3 or 4 ft/sec (0.9 to 1.2 m/sec), and the use of quick-closing valves should be minimized. In addition, expansion chambers should be inserted in the system if long lengths cannot be avoided. These expansion chambers contain a column of air which acts as a cushion and damps out a nominal pressure pulse before it can significantly harm the pipe.

The water hammer tests were designed to determine whether one kind of joint or joints made under particular conditions were most likely to fail due to the water hammer phenomenon. The tests were conducted on (1) 3/4-in. (18-mm)-diameter PVC and CPVC pipe with solvent-cemented joints made under temperature conditions ranging from 25° to 110°F (−4° to 43°C); (2) 3/4-in. (18-mm) PVC with threaded joints; and (3) PE and PB pipe assembled with compression insert fittings. The pipes were made up of 4- to 5-ft-long (1.2- to 1.5-m) sections with joints between sections. Joints were made up at the various conditions, noted, and tagged. Each pipe was supported at 4-ft (1.2-m) intervals on 3/4-in. (18-mm)-wide supports which did not restrain the pipe. No offsets were included in the pipe run, since offsets tend to absorb energy from the system. The line length in each case was 50 ft (15 m).

A solenoid-operated valve similar to the type used in automatic washers and dishwashers was used (Figure 2). A timer (Figure 3) was included to give 15-sec on and 15-sec off periods of operation. Its closure time was 0.1 sec. This setup resulted in pressure pulses of 105 to 140 psi (724 to 966 kPa). The number of cycles used in the testing was selected to represent the operation of the typical residential washing machine or dishwasher.

The velocity of liquid in the line was varied by installing a bladder-type storage tank (Figure 4). The tank was filled with water; compressed air was then added to the tank to increase the pressure. Line pressure of 50 psi (345 kPa) resulted in 3 ft/sec (0.9 m/sec) velocity, and 90 psi (621 kPa) tank pressure resulted in 4 ft/sec (1.2 m/sec) velocity. These were the pressures and velocities used in the testing.

Initially, CPVC pipe and joints were tested. The pipe was subjected to 3270 pulses of 105 to 140 psi (724 to 966 kPa) over-line pressure. Pulse pressures were measured at the tank, which was 50 ft (15 m) from the solenoid valve. No leaks or other evidence of failures were noted.

PE and PB pipes were tested under similar conditions with no failures.

PVC pipe was tested in two configurations—schedule 40 pipe with solvent-welded joints and schedule 80 pipe with threaded joints. There were no failures in 3000 cycles at 105 to 140 psi (724 to 966 kPa).

⁵G. M. Flair and J. C. Geyer, *Water Supply and Waste-Water Disposal* (John Wiley & Sons, 1954), p 315.

⁶D. A. Chasis, *Plastic Piping Systems* (Industrial Press, Inc., 1976), p 31.

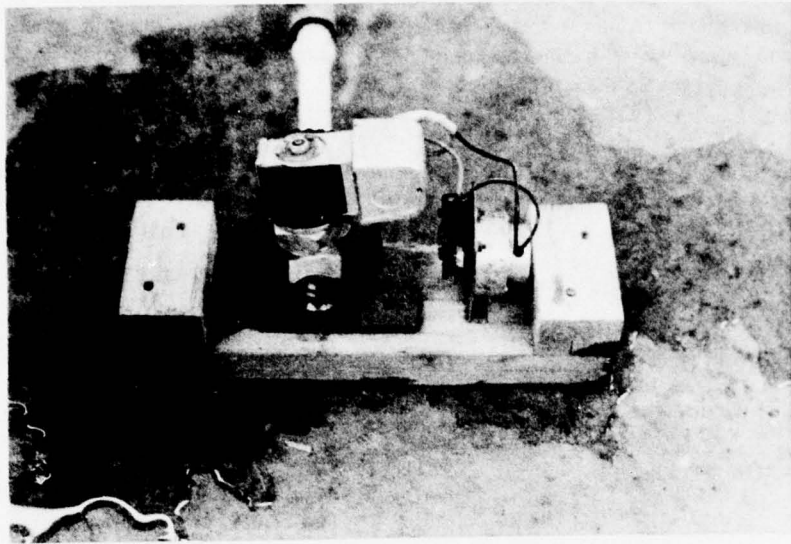


Figure 2. Solenoid-operated valve.

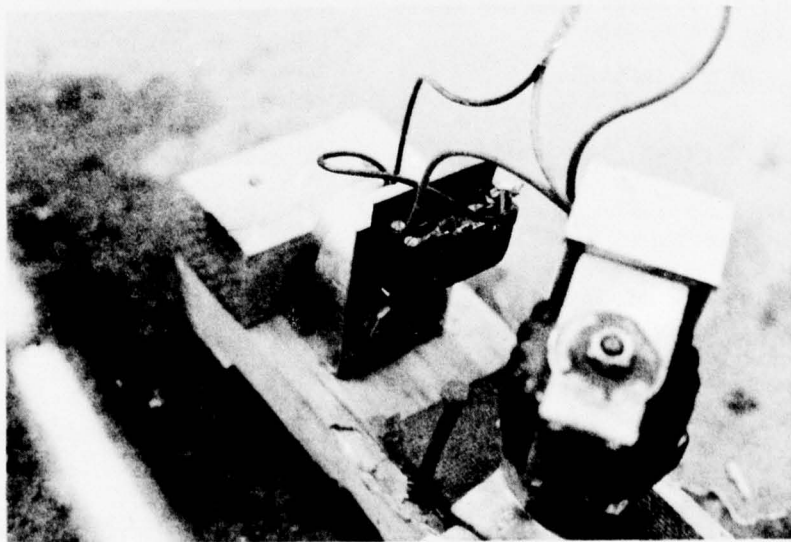


Figure 3. Timer.

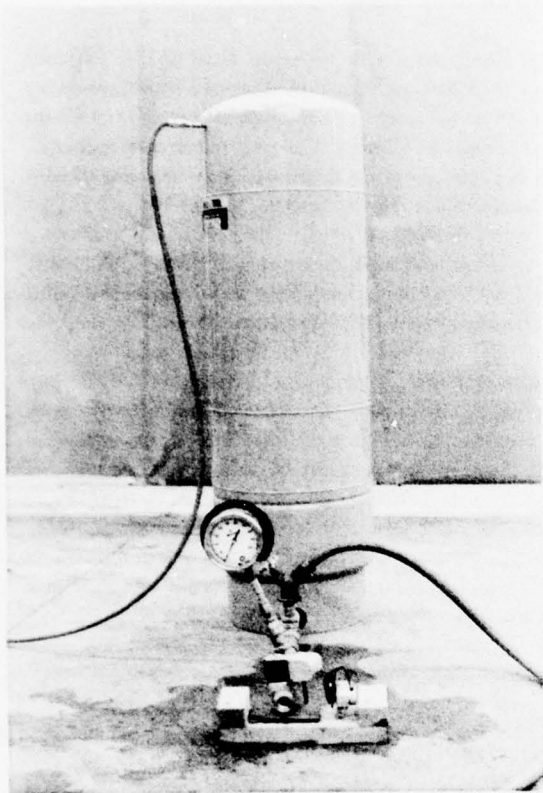


Figure 4. Storage tank.

Schedule 40 CPVC pipe with solvent-cemented joints was retested with pressure pulses of 105 psi (724 kPa) and alternate days of cold (45°F [7°C]) and hot water (140°F [60°C]). The system was set up such that a resonating cycle of 4 pulses/sec occurred. Approximately 120,000 cycles per work day were run until 1,133,600 cycles were completed. No failures occurred in either the pipe or the joints formed at various temperature conditions. There was essentially no difference in performance with hot or cold water.

The test results indicated that properly designed and installed plastic pipe can withstand many nominal pressure pulses occurring rapidly for several hours' duration in either hot or cold water lines.

4 SELECTION GUIDE

Any decision on whether to use plastic pipe for a particular application should be preceded by examination of the possible advantages and disadvantages of both plastic pipe and other pipe materials. In evaluating piping for plumbing systems, performance in the system should be the chief criterion; comparing the properties of the materials of which the pipes are made is not a meaningful way to assess performance. Since according to NBS "there is considerable predisposition in the plumbing industry regarding the choice of piping materials,"⁷ it is important that care be taken in reaching a fair decision. The following discussion of the attributes of metal piping systems (including cast iron, galvanized iron or steel, copper, brass, bronze, and stainless steel piping materials) and thermoplastic piping systems will help in reaching the decision.

Metal Piping Systems

Potential Advantages

The following are potential advantages of metal piping systems:⁸

- a. The structural strength of metal piping is high, and the dimensions change little over a normal range of temperatures for plumbing service.
- b. Movement of the pipe from hydraulic loads and thermal effects is small, so clearances need only be nominal and control of thermal expansion or contraction can readily be accomplished with standard techniques.
- c. Since metals are noncombustible at the temperatures usually encountered in building fires, toxic products are not produced. Care is, however, needed in the construction of plumbing chases and walls to control the spread of fire and the toxic products from combustible building materials.
- d. Susceptibility to bacteriological and biological attack is insignificant.
- e. Grounding of electrical appliances and circuits is convenient, since metals are conductors.

⁷R. S. Wyly, et al., *Review of Standards and Other Information on Thermoplastic Piping in Residential Plumbing*, Building Science Series 68 (National Bureau of Standards, May 1975), p 9.

⁸Wyly, et al., pp 9-12.

f. The heavy mass of cast iron or steel piping helps to dampen vibrations that could result in unwanted noise.

g. Durability varies with the metal selected for use. Data obtained through experience permits selection of the metal which will provide the durability needed for a particular use.

h. Satisfactory mechanical and chemical cleaning procedures have been available for many years; however, some augers and chemicals can reduce the life of the pipe.

Potential Disadvantages

Potential disadvantages of metal piping include the following:⁹

a. Corrosion may affect all metal piping to some extent. Copper may corrode, particularly around brazed joints or in urinal drain piping. Stray electric currents moving along a pipe may cause corrosion where the current enters the earth. Dissolved carbon dioxide in the water causes corrosion of ferrous as well as nonferrous pipes. Iron pipe readily corrodes, forming a pipe-clogging rust scale. Deep pitting of iron pipe may occur, particularly with acid waters. Steel pipe joints may fail in a corrosive environment (e.g., burial in a corrosive soil) because the protective galvanizing is removed in the threading operations. Protective coatings may be required in such cases.

b. Some of the jointing techniques make assembly of piping tedious. Pipe and fittings may be relatively heavy, necessitating helpers for each plumber.

c. Accommodating some of the metallic piping may create space problems, particularly where reduced-size structural elements are to be used, since the piping has a large overall outside diameter and bulky joints.

d. For heavy metal pipes, the structural loading is particularly high under seismic conditions.

e. Accumulation of deposits from corrosion, fluid suspensions, and chemical precipitation can seriously reduce inside diameter and hydraulic flow, particularly in the case of ferrous piping in hard water.

f. Contamination of water may occur from lead soldering, copper corrosion, and rusting. Water composition and temperature are major determinants of the extent of this problem.

g. Condensation of moisture from the air on cold pipes increases exterior corrosion and promotes damp conditions for growth of fungus and icing of poorly insulated cavities. Similarly, the high thermal conductivities of metal pipes contribute to frost closures of vent terminals in north latitudes.

h. Sound transmission by conduction is high in stiff metal systems; thus, knocking initiated at one point can be transmitted throughout the building.

Many of the potential disadvantages of metallic piping for plumbing may be overcome through adherence to generally accepted good practice in design and installation. For example, where water characteristics are adverse, a water quality control program or an alternate choice of material can provide an acceptable solution. Use of resilient gaskets and supports can reduce sound transmission, and use of better insulation and humidity control can reduce exterior condensation.

Thermoplastic Piping Systems

Potential Advantages

The following are potential advantages of thermoplastic piping systems:¹⁰

a. Because the material is lightweight, individuals can handle it easily, and dead-load forces on the structure are reduced.

b. Corrosion resistance to water and most household chemicals is high. This results in a cost savings.

c. Deposits do not accumulate to the extent associated with some metal piping materials.

d. Electrolytic action and electrical conductivity are insignificant; this could reduce the problems of electrolytic corrosion.

e. During construction, fire hazards are eliminated, since the torches used for brazing or soldering metal pipe and fittings are not used in joining thermoplastic pipe.

⁹R. S. Wyly, et al., *Review of Standards and Other Information on Thermoplastic Piping in Residential Housing*, Building Science Series 68 (National Bureau of Standards, May 1975), pp 9-12.

¹⁰Wyly, et al., pp 9-12.

f. Thermoplastic pipe's lower stiffness reduces sound transmission along its length compared to that along metals.

g. Combined material and labor factors can produce a considerable cost reduction (15 to 50 percent) through the use of plastic pipe.¹¹

h. Production of plastic pipe for a particular project is more energy-efficient than production of metallic pipe for the same installation. This factor's significance may increase as the cost per energy unit continues to climb.

Potential Disadvantages

The potential disadvantages of thermoplastic piping systems include:¹²

a. Each particular thermoplastic has a maximum service temperature which sets the upper limit to which the pipe may be heated without damage. When heated above this temperature, the pipe material will soften and deform; upon cooling, it will harden to the deformed shape and dimensions. These critical temperatures for the thermoplastics considered here are near the temperature of boiling water; hence, it is important to determine that the normal service temperature will be below the maximum service temperature. In addition, the strength decreases as the temperature increases, which is particularly important in pressure piping. Therefore, both the service pressure and service temperature must be considered in specifying the appropriate material and the wall thickness of the pipe.

b. Movement of piping resulting from hydraulic loads and thermal effects is relatively high compared to metals. Special attention must therefore be given to installation details.

c. Mechanical cleaning to remove obstructions in drains and vents with conventional equipment used to clean metallic systems (e.g., power-driven auger, rodding, or scraping mechanisms) may damage piping. Care must be taken in selecting the mechanisms to be used.

d. Controlling the spread of fire, smoke, and toxic gases from plumbing chases or walls containing thermo-

plastic materials may require special attention to installation details.

e. Grounding of electrical appliances and electrical circuits must be accomplished via a separate conductor and ground spike when thermoplastic water service piping is used.

f. If thermoplastics are to be exposed to the sun for long periods, they may require special stabilization to prevent degradation due to ultraviolet radiation. Thus, choice of the material to be used requires care.

g. Due to its light weight, thermoplastic pipe offers little acoustical damping to airborne sound; special measures may therefore be required to counteract any unpleasant sounds.

h. Because of the relatively short period of experience with thermoplastic piping for residential plumbing, compared to that with metals, and because of the unreliability and incompleteness of data on experience, some degree of uncertainty exists regarding thermoplastic piping's long-term durability and its susceptibility to bacteriological and biological attack. Laboratory tests have produced chemically induced cracking (environmental stress cracking) of thermoplastics. This phenomenon is not well defined, nor is its relative significance established in relation to thermoplastic piping systems in service. This is largely because of uncertainty as to the relationship between the typical pattern of service exposure and the laboratory conditions under which stress cracking can be produced.

Many of the potential disadvantages in using thermoplastic piping systems in plumbing can be resolved with sensible design, assembly, and use. Overcoming the disadvantages is not costly if the housing design incorporates the requirements prior to construction. Thermoplastic piping systems must be evaluated against meaningful working criteria in a service environment. Each material may have characteristics that compare favorably with those of another material, but it can also have its own particular set of problems which must be resolved if the material is to be used successfully in a working system. With traditional materials, resolution of many problems has come about gradually with the development of improved techniques and products. Because thermoplastic piping technology is still developing, not all problems requiring experience to resolve have yet been settled to the satisfaction of all concerned groups.

¹¹ D. A. Chasis, *Plastic Piping Systems* (Industrial Press, Inc., 1976), pp 135-155.

¹² Wyly, et al., pp 9-12.

Selecting a Thermoplastic System

After weighing the potential advantages and disadvantages of the different kinds of pipe, a selection can be made. The best way to select the type of plastic pipe for a particular application is to base the selection on the experiences of others who have used the material successfully. Table 7 presents general guidance for material selection for a variety of typical applications; these selections are based on experience in numerous installations. Many of the standards listed in Appendix A also indicate appropriate matches between material and application. Any good book on plastic pipe will give sizes, ratings, and types of pipe available. If a material is being selected for chemical wastes, plastic pipe manufacturers' published literature should be consulted for recommendations.

5 IMPACT ON CORPS OF ENGINEERS GUIDE SPECIFICATIONS

Corps of Engineers Guide Specifications were reviewed to determine which of them may be affected if plastic pipe is allowed for general use (as indicated by the applications in Table 7) in construction and rehabilitation work. Appendix D lists the Guide Specifications which may require revision and identifies the type(s) of plastic pipe which could be included as an alternate material.

6 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The investigations documented in this report have led to several conclusions:

a. Plastic pipe is satisfactory for use in military facilities based on the successful use by civilian builders of billions of pounds per year of plastic pipe which is produced under excellent quality control conditions and which meets definite standards and specifications.

b. Significant cost savings in both material and labor can be realized by using plastic pipe; up to about 50 percent of the cost of material and labor of an installation can be saved. Plastic pipe's corrosion resistance can produce additional savings.

c. Plastic pipe is available in a range of sizes and pressure ratings which covers most water and gas distribution, electrical conduit, DWV, and sewer system needs.

d. Plastic pipe costs less to produce in terms of energy required than does metallic pipe. As energy unit costs go up, this factor will become more significant.

e. Forming good joints requires that personnel doing the joining receive training from someone familiar with the requirements and have some opportunity for practice. Good, serviceable joints can be made with proper use of the currently available methods.

f. Indiscriminate and abusive applications of certain commercially available cleaning agents and methods can harm plastic pipe DWV and sewer systems. However, prudent use of both chemical and mechanical cleaning mechanisms will not damage such systems.

g. Properly designed and installed plastic pipe can withstand many nominal pressure pulses occurring rapidly for several hours' duration in either hot or cold water lines without failure.

Recommendations

It is recommended that plastic pipe be authorized for use as an alternate material for water distribution, irrigation, gas distribution, DWV, and sewer systems under the same criteria as it is allowed in civilian applications and that applicable guide specifications be modified to show such authorization.

It is further recommended that only materials identified as meeting ASTM and NSF standards be used. To assure quality control, it is recommended that Corps of Engineers contractors be required to use qualified installers or to have a representative from the pipe manufacturer provide training to the installers and be present during the first full day of installation to observe the procedures employed.

Table 7
Plastic Pipe Selection Guide*

Application	Pipe Material	Usual Jointing Method
Water distribution and branch lines	PVC	O-Ring, gasketed fittings, solvent-cemented
Water service pipe	PVC, PB, PE	PVC: solvent-cemented, O-Ring, threaded Schedule 80 or greater PE, PB: compression insert
Interior plumbing		
a. Cold water	PVC	Solvent-cemented (threaded, Schedule 80 or greater)
b. Hot water	CPVC, PB	Solvent-cemented, compression insert
Gas mains	PE PVC	Butt fusion O-Ring, flanged
Gas service pipe	PE PVC	Compression insert Threaded, solvent cemented
Drain pipe	PVC, ABS, PE	PVC, ABS: solvent-cemented PE: butt heat fusion, electrical resistance
DWV	PVC, ABS	Solvent-cemented
Sewer mains	PVC, ABS, PE	PVC, ABS: solvent-cemented, O-ring PE: butt heat fusion, flanging
Water well casing	PVC	Solvent-cemented, Restrained O-Ring, threaded
Water well pipe (submergible pump, etc.)	PE, PB	Compression insert Compression flared (PB only)
Irrigation		
a. High head	PVC, PE	PVC: solvent-cemented, O-ring PE: butt heat fusion
b. Low head	PVC, PE, PB	PVC: solvent-cemented, O-ring PB, PE: butt heat fusion, compression insert
c. Lawn and turf	PVC, PE, PB	PVC: O-ring, solvent-cemented PE, PB: butt heat fusion, compression insert
d. Drip	PE	Compression insert
Electrical conduct		
a. Above ground	PVC, PE	PVC: Solvent-cemented, O-ring PE: butt heat fusion, flanged
b. Below ground	PVC, PE, ABS	PVC, ABS: solvent-cemented, O-ring PE: butt heat fusion, flanged

*Data derived from D. A. Chasis, *Plastic Piping Systems* (Industrial Press, Inc., 1976); trade journals; and manufacturers' literature.

CITED REFERENCES

- Anon., *AWWA Standard for Polyvinyl Chloride (PVC) Pressure Pipe, 4 in. Through 12 in. for Water* (American Water Works Association, 1975), p 12.
- Chasis, D. A., *Plastic Piping Systems* (Industrial Press, Inc., 1976), pp 135-155, 31.
- Facts and Figures of the Plastics Industry* (Society of the Plastics Industry, Inc., August 1975).
- Flair, G. M. and J. C. Geyer, *Water Supply and Waste-Water Disposal* (John Wiley & Sons, 1954), p 315.
- Wyly, R. S., et al., *Review of Standards and Other Information on Thermoplastic Piping in Residential Housing*, Building Science Series 68 (National Bureau of Standards, May 1975), pp 9-12.

UNCITED REFERENCES

- Basic Plumbing Code*, 2nd edition (Building Officials and Code Administrators International, 1970 with 1973 supplement).
- Blenderman, Louis, *Design of Plumbing and Drainage Systems*, 2nd ed. (Industrial Press, Inc., 1963).
- Canadian Plumbing Code* (Canadian Standards Association, 1974).
- National Standard Plumbing Code* (American Society of Plumbing Engineers and National Association of Plumbing-Heating-Cooling Contractors, 1973).
- Rigid Thermoplastic Pipe and Fittings for Residential Drain-Waste and Vent Systems* (National Academy of Sciences, 1966).
- Southern Standard Plumbing Code (Southern Building Code Congress, 1971).
- Uniform Plumbing Code* (International Association of Plumbing and Mechanical Officials, 1973).

APPENDIX A: STANDARDS RELATED TO PLASTIC PIPE

ASTM

American Society for Testing and Materials
1916 Race St
Philadelphia, PA 19103

For the purposes of this report, the ASTM Standards were divided into three groups: specifications for plastic pipe, fittings, and related materials; methods of testing thermoplastic pipe and tubing; and recommended practices. The listing also provides cross-references to ANSI and NBS Standards. ANSI's plastic pipe standards are cataloged in their B72 and K65 series. Since there is an identical or more recently updated ASTM standard for each standard in these series, the ANSI designations are presented in parentheses after the corresponding ASTM Standard. Where applicable, NBS product standards (PS) related to plastic pipe are also cross-referenced. However, these PSs are no longer available.

Specifications for Plastic Pipe, Fittings and Related Materials

a. Acrylonitrile-Butadiene-Styrene (ABS)

D 1527-73a, Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80. (ANSI B72.5 - 1971) (NBS PS18-69)

D 1788-73, Rigid Acrylonitrile-Butadiene-Styrene (ABS) Plastics. (ANSI K65.205 - 1971)

D 2282-73a, Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR). (ANSI B72.3 - 1967) (NBS PS19-69)

D 2465-73, Threaded Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40. (ANSI K65.165 - 1971)

D 2468-73, Socket-Type Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40. (ANSI K65.164 - 1971)

D 2469-73, Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 80. (ANSI K65.163 - 1971)

D 2661-74, Acrylonitrile-Butadiene-Styrene (ABS) Plastic Drain, Waste, and Vent Pipe and Fittings. (ANSI B72.18 - 1971)

D 2680-74, Acrylonitrile-Butadiene-Styrene (ABS) Composite Sewer Piping.

D 2751-73, Acrylonitrile-Butadiene-Styrene (ABS) Sewer Pipe and Fittings. (ANSI K65.59 - 1971)

b. Poly(vinyl chloride) (PVC)

D 1785-69, Poly(vinyl chloride) (PVC) Compounds and Chlorinated Poly(vinyl chloride) (CPVC) Compounds, Rigid. (ANSI K65.206 - 1971)

D 1785-74, Poly(vinyl chloride) (PVC) Plastic Pipe, Schedule 40, 80, and 120. (ANSI B72.7 - 1971) (includes CPVC 4116) (NBS PS21-70)

D 2241-74, Poly(vinyl chloride) (PVC) Plastic Pipe (SDR-PR and Class T). (ANSI B72.2 - 1967) (NBS PS22-70)

D 2464-74, Threaded Poly(vinyl chloride) (PVC) Plastic Pipe Fittings, Schedule 80. (ANSI K65.166 - 1971)

D 2466-74, Socket-type Poly(vinyl chloride) (PVC) Plastic Pipe Fittings, Schedule 40.

D 2467-74, Socket-type Poly(vinyl chloride) (PVC) Plastic Pipe Fittings, Schedule 80.

D 2265-74, Poly(vinyl chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings. (ANSI K65.56 - 1971)

D 2672-73, Bell-end Poly(vinyl chloride) (PVC) Pipe. (ANSI B72.20 - 1971)

D 2729-72, Poly(vinyl chloride) (PVC) Sewer Pipe and Fittings.

D 2740-74, Poly(vinyl chloride) (PVC) Plastic Tubing. (ANSI B72.22 - 1971)

D 2836-72, Filled Poly(vinyl chloride) (PVC) Sewer Pipe.

D 2949-71, Three-Inch Thin Wall Poly(vinyl chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings.

D 3033-73, Type PSP Poly(vinyl chloride) Sewer Pipe and Fittings.

D 3034-73a, Type PSM Poly(vinyl chloride) Sewer Pipe and Fittings.

D 3036-73, Poly(vinyl chloride) (PVC) Plastic Line Couplings, Socket-type.

c. Chlorinated Poly(vinyl chloride) (CPVC)

D 2846-73, Chlorinated Poly(vinyl chloride) (CPVC) Plastic Hot Water Distribution Systems.

d. Polyethylene (PE)

D 1248-74, Polyethylene Plastics Molding and Extrusion Materials.

D 2104-74, Polyethylene (PE) Plastic Pipe, Schedule 40. (ANSI B72.8 - 1971) (NBS PS10-69)

D 2239-74, Polyethylene (PE) Plastic Pipe (SDR-PR). (ANSI B72.1 - 1967) (NBS PS11-69)

D 2447-74, Polyethylene (PE) Plastic Pipe, Schedules 40 and 80 Based on Outside Diameter. (ANSI B72.13-1971) (NBS PS12-69)

D 2609-73, Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe.

D 2610-73, Butt Fashion Polyethylene (PE) Plastic Pipe Fittings, Schedule 40. (ANSI K65.160 - 1971)

D 2611-73, Butt Fashion Polyethylene (PE) Plastic Pipe Fittings, Schedule 80. (ANSI K65.159 - 1971)

D 2683-70, Socket-Type Polyethylene (PE) Fittings for SDR11.0 Polyethylene Pipe.

D 2737-74, Polyethylene (PE) Plastic Tubing.

D 3035-74, Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter.

D 3197-73, Insert-type Polyethylene Fusian Fittings for SDR11.0 Polyethylene Pipe.

D 3261-73, Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.

Note: In addition to these standards for the common residential plastic pipes, ASTM lists standards for cellulose-acetate-butyrate (CAB), polybutylene (PB), and styrene-rubber (SR) thermoplastic pipes and fittings, and reinforced thermosetting plastic pipes and fittings.

e. Specifications for Plastic Piping Solvent Cements

D 2235-73, Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings. (ANSI B72.23 - 1971)

D 2564-73a, Solvent Cements for Poly(Vinyl chloride) (PVC) Plastic Pipe and Fittings. (ANSI B72.16 - 1971).

D 3138-72, Solvent Cements for Joining Acrylonitrile-Butadiene-Styrene (ABS) Pipe and Fittings to Poly(vinyl chloride) (PVC) Pipe and Fittings for Non-pressure Applications.

Methods of Testing of Thermoplastic Pipe and Tubing

D 1180-57(1972), Bursting Strength of Round Rigid Plastic Tubing.

D 1598-74, Time-to-Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure. (ANSI B72.6 - 1971).

D 1599-69, Short-Time Rupture Strength of Plastic Pipe, Tubing and Fittings. (ANSI K65.53 - 1971).

D 2122-70, Determining Dimensions of Thermoplastic Pipe and Fittings.

D 2152-67 (1972), Quality of Extruded Poly(vinyl chloride) Pipe by Acetone Immersion. (ANSI B72.9 - 1971).

D 2290-69, Apparent Tensile Strength of Ring and Tubular Plastics by Split Disk Method.

D 2412-68, External Loading Properties of Plastic Pipe by Parallel-Plate Loading. (ANSI B72.11 - 1971).

D 2444-70, Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight). (ANSI K65.169 - 1971).

D 2837-69, Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials. (ANSI K65.153 - 1971).

D 2924-71, External Pressure Resistance of Plastic Pipe.

Recommended Practices

D 2153-67(1972), Calculating Stress in Plastic Pipe Under Internal Pressure. (ANSI B72.10 - 1971).

D 2321-72, Underground Installation of Flexible Thermoplastic Sewer Pipe. (ANSI K65.171 - 1971).

D 2657-67(1972), Heat Joining of Thermoplastic Pipe and Fittings. (ANSI B72.17 - 1971).

D 2749-68(1973), Standard Symbols for Dimensions of Plastic Pipe Fittings. (ANSI K65.58 - 1971).

D 2774-72, Underground Installation of Thermoplastic Pressure Piping.

D 2855-73, Making Solvent Cemented Joints with Poly(vinyl chloride) (PVC) Pipe and Fittings. (ANSI K65.55 - 1971).

D 3140-72, Flaring Polyolefin Pipe and Tubing.

D 3311-74, Drain, Waste and Vent (DWV) Plastic Fitting Patterns.

F 402-74, Safe Handling of Solvent Cements Used for Joining Thermoplastic Pipe and Fittings.

Federal Specifications

Specifications Sales (3FRSBS)
Building 197
Washington Naval Yard
General Services Administration
Washington, DC 20407

L-F-1546A, Fittings, Plastic Pipe (Adapters, Couplings, Elbows, and Tees for Polyethylene Pipe) (18 September 1973).

L-P-315c, Pipe, Plastic (Polyethylene, PE, SDR-PR) (3 May 1972).

P-P-320b, Pipe and Fittings, Plastic (PVC, Drain, Waste and Vent) (8 March 1973), Notice 1 (14 May 1973).

L-P-322b, Pipe and Fittings, Plastic (ABS, Drain, Waste and Vent) (4 May 1973).

Department of Defense Military Standards

Commanding Office
Naval Publications and Forms Center
5108 Tabor Ave
Philadelphia, PA 19120

MIL-P-14529B, Pipe, Extruded, Thermoplastic (6 May 1970).

MIL-P-21922A, Plastic Rods and Tubes, Polyethylene (11 July 1966).

MIL-A-22010A(1), Adhesive, Solvent-Type, Polyvinyl Chloride (17 February 1961), Amendment (9 June 1961).

MIL-P-22011A, Pipe Fittings, Plastic, Rigid, High Impact Polyvinyl Chloride (PVC), and Poly 1, 2, - Dichloroethylene (13 January 1969).

MIL-P-22634A, Pipe and Pipe Fittings, Polyethylene, for Low-Pressure Waste and Drainage Systems (11 February 1966).

MIL-P-82056(1), Pipe and Pipe Fittings, Plastic, for Drain, Waste and Vent Service (29 January 1968), and Amendment (27 May 1969).

FHA/HUD

Materials Acceptance Section, FTEX
Federal Housing Administration
Washington, DC 20412

FHA MR-562, Rigid Chlorinated Polyvinyl Chloride (CPVC) Hi/Temp Water Pipe and Fittings (3 November 1967).

FHA MR-563, PVC Plastic Drainage and Vent Pipe and Fittings (6 November 1967).

FHA UM-26c, Plastic Drain and Sewer Drain and Fittings (7 December 1971).

FHA UM-31e, Polyethylene Plastic Pipe and Fittings for Domestic Water Service (1 August 1966).

FHA UM-41a, PVC Plastic Pipe and Fittings for Domestic Water Service (15 April 1969).

FHA UM-43, Acrylonitrile-Butadiene-Styrene Plastic Pipe and Fittings for Domestic Water Service (1 November 1966).

FHA UM-49, ABS and PVC Plastic Drainage and Vent Pipe and Fittings, FHA 4550.49 (1 May 1968).

FHA UM-53a, Polyvinyl Chloride Plastic Drainage, Waste, and Vent Pipe and Fittings (22 February 1971).

FHA UM-54, ABS (Acrylonitrile-Butadiene-Styrene) Plastic Drainage, Waste, and Vent Pipe and Fittings (20 February 1970).

FHA UM-56, Polyethylene Plastic Drainage, Waste, and Vent Pipe and Fittings (5 May 1970).

FHA UM-61a, (CPVC) Hot and Cold Water Distribution Systems - Chlorinated Poly(vinyl chloride) (20 August 1971).

HUD Minimum Property Standards, Volume 1, One and Two Family Dwellings, 1973 Edition, No. 4900.1.

HUD Minimum Property Standards, Volume 2, Multifamily Housing, 1973 Edition, No. 4910.1.

HUD Minimum Property Standards, Volume 3, Care-Type Housing, 1973 Edition, No. 4920.1.

Note: The Minimum Property Standards are sold by the Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

NSF

National Sanitation Foundation
NSF Building
Ann Arbor, MI 48105

NSF Standard No. 14, Thermoplastic Materials, Pipe, Fittings, Valves, Traps and Joining Materials (October 1965).

NSF Seal of Approval Listing of Plastic Materials, Pipe, Fittings and Appurtenances for Potable Water and Waste Water (NSF Testing Laboratory) (issued in March each year).

IAPMO

International Association of Plumbing and Mechanical Officials
5032 Alhambra Ave
Los Angeles, CA 90032

Installation Standards (IS)

IAPMO IS-1-71, Installation Standard for Non-Metallic Building Sewers.

IAPMO IS-5-71, Installation Standard for ABS Building Drain, Waste and Vent Pipe and Fittings.

IAPMO IS-7-71, Installation Standard for Polyethylene Building Supply for Water Service and Yard Piping.

IAPMO IS-8-71, Installation Standard for Solvent Cemented PVC Pipe for Water Service and Yard Piping.

IAPMO IS-9-71, Installation Standard for PVC Building Drain, Waste and Vent Pipe, and Fittings.

Product Standards (PS)

IAPMO PS-17-71, Supplemental Standard to ASTM D 2661-68 Acrylonitrile-Butadiene-Styrene (ABS) Plastic Drain, Waste and Vent Pipe and Fittings and Addendum.

IAPMO PS-24-71, Polyethylene Pipe for Cold Water Service and Yard Piping.

IAPMO PS-25-69, Fittings for Joining Polyethylene Pipe for Water Service and Yard Piping.

IAPMO PS-26-69, Supplemental Standard to ASTM D 2665: Poly(vinyl chloride) (PVC) Plastic Drain and Vent Pipe and Fittings.

CSA

Canadian Standards Association, Inc.
178 Rexdale Blvd.
Rexdale, Ontario, Canada M9W1R3

B 137.0-1973, Definitions, General Requirements and Methods of Testing for Thermoplastic Piping.

B 137.1-1970(R-71), Polyethylene Pipe for Cold Water Service.

B 137.2.1-1970, Acrylonitrile-Butadiene-Styrene (ABS) Pipe for Pressure Application, IPS Dimensions.

B 137.3-1972, Rigid Poly(vinyl chloride) (PVC) Pipe for Pressure Application.

B 137.6-1971, Chlorinated Poly(vinyl chloride) (CPVC) Plastic Piping for Hot and Cold Water Distribution Systems.

B 181.1-1973, Acrylonitrile - Butadiene - Styrene Drain, Waste and Vent (ABS-DWV) Pipe and Pipe Fittings.

B 181.2-1973, Poly(vinyl chloride) Drain, Waste and Vent Pipe and Pipe Fittings.

B 181.11-1967(R-70), Recommended Practice for the Installation of ABS Drain, Waste and Vent Pipe and Pipe Fittings.

B 181.12-1967(R-70), Recommended Practice for the Installation of PVC Drain, Waste and Vent Pipe and Pipe Fittings.

B 181.1-1967, Plastic Drain and Sewer Pipe and Pipe Fittings for Use Underground.

B 182.11-1967, Recommended Practice for the Installation of Plastic Drain and Sewer Pipe and Pipe Fittings.

PPI

Plastic Pipe Institute
240 Park Ave
New York, NY 10017

PPI Technical Reports (TR)

TR 1, A Glossary of Plastic Piping Terms (November 1968).

TR 2, Recommended Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe (October 1968). (Replaced by ASTM D 2837-69).

TR 3, Policies and Procedures on Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe (August 1973).

TR 4, Recommended Hydrostatic Strengths and Design Stresses for Thermoplastic Compounds (March 1974).

TR 5, List of Standards for Plastic Piping (May 1974).

TR 6, Recommended Standard Terminology for Dimensions of Plastic Pipe Fittings (February 1968). (Replaced by ASTM D 2749-68 [1973]).

TR 7, Recommended Method for Calculation of Nominal Weight of Plastic Pipe (March 1968).

TR 8, Polyethylene Piping Installation Procedures (April 1968).

TR 9, Recommended Standard Service (Design) Factors for Pressure Applications of Thermoplastic Pipe Materials (August 1973).

TR 10, Recommended Practice for Making Solvent-Cemented Joints with PVC Pipe and Fittings (February 1969).

TR 11, Resistance of Thermoplastic Piping Materials to Micro- and Macro-Biological Attack (February 1969).

TR 12, Acrylonitrile-Butadiene-Styrene Plastic (ABS) Piping Installation Procedures (April 1973).

TR 13, Polyvinyl Chloride (PVC) Plastic Piping Design and Installation (August 1973).

TR 14, Water Flow Characteristics of Thermoplastic Pipe (March 1971).

TR 15, Recommended Practice for Bending Polyvinyl Chloride (PVC) Conduit in the Field (August 1973).

TR 16, Thermoplastic Water Piping Systems (August 1973).

TR 17, Thermoplastic Piping for Swimming Pool Water Circulation Systems (August 1973).

TR 18, Weatherability of Thermoplastic Piping (March 1973).

TR 19, Thermoplastic Piping for the Transport of Chemicals (August 1973).

TR 20, Joining Polyolefin Pipe (September 1973).

TR 21, Thermal Expansion and Contraction of Plastic Pipe (September 1973).

PPI Technical Notes (TN)

TN 1, Sealants for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Piping (March 1970).

TN 2, Sealants for Polyvinyl chloride (PVC) Plastic Piping (March 1970).

TN 3, Electrical Grounding (May 1971).

TN 6, Recommendations for Coiling Polyethylene Plastic Pipe and Tubing (March 1972).

TN 7, The Nature of Hydrostatic Time-to-Rupture Plots (September 1973).

TN 8, Making Threaded Joints with Thermoplastic Pipe and Fittings (August 1973).

TN 9, Recommendations for Coiling Poly(vinyl chloride) (PVC) Plastic Pipe and Tubings (August 1973).

AWWA

American Water Works Association
6666 West Quincy
Denver, CO 80235

R281 and R1015, Developments in Plastic Pipe.

AGA

American Gas Association
1515 Wilson Blvd
Arlington, VA 22209

AGA references other standards and specifications.

**APPENDIX B:
NBS CODE ACCEPTANCE SURVEY***

A - Approved for all types of structures above and below ground.

C - Commercial or premium grade approved for use outside building line.

G - Approved for above-ground use only.

H - Approved for use in hot and cold water supply lines within buildings.

L - Approved for use in single-family homes and low-rise apartments.

N - Not covered by code.

O - Approved for below-ground use outside building line.

P - Premium grade only approved for use outside building line.

S - Approved for use in single-family and (in some codes) 2-family homes only.

X - Prohibited.

1 - Also approved for use in commercial structures.

2 - Also permitted in high-rise apartments.

3 - Up to 60 feet in height.

4 - Residential and low-rise apartments.

5 - Cold water only.

*From R. S. Wyly, et al., *Review of Standards and Other Information on Thermoplastic Piping in Residential Housing*, Building Science Series 68 (National Bureau of Standards, May 1975).

Table B1
Matrix Presentation of Plumbing Code Provisions in
68 Cities Throughout the United States,
Regulating Selected Uses of Four
Thermoplastic Piping Materials

	PVC Plastic DWV	ABS Plastic DWV	PE Plastic Water Pipe	CPVC Plastic Water Pipe		PVC Plastic DWV	ABS Plastic DWV	PE Plastic Water Pipe	CPVC Plastic Water Pipe
Albany, N. Y.	N	N	N	N	Jacksonville, Fla.	A	A	C	X
Baltimore Md.	L ¹	L ¹	X	X	Kansas City, Mo.	A	A	X	X
Billings, Mont.	L	X	C	X	Las Vegas, Nev.	S ⁵	S ⁵	C	O
Boise, Idaho	S	S	X	X	Little Rock, Ar.	S	S	P	O
Boston, Mass.	S	S	X	X	Los Angeles, Cal.	L	L	P	H
Buffalo, N. Y.	A	G	C	O	Madison, Wis.	A	A	P	H
Charlotte, N. C.	A	A	P	O	Memphis, Tenn.	L	L	C	X
Chicago, Ill.	X	X	X	X	Miami, Fla.	A	A	X	O
Cincinnati, Ohio	A	A	X	X	Milwaukee, Wis.	L ⁵	L ⁵	C	H
Cleveland, Ohio	G	S	G	H	Minneapolis, Minn.	S	S	P	X
Colorado Springs, Col.	A	A	P	H	Mobile, Ala.	A ³	A ³	C	X
Columbia, S. C.	A ³	A ³	C	O	Montgomery, Ala.	L	L	X	X
Columbus, Ohio	A	A	C	X	Nashville, Tenn.	A ³	A ³	X	X
Dallas, Texas	A	A	P	O	Newport News, Va.	L ¹	L ¹	C	O
Dayton, Ohio	A	A	C	X	New York, N. Y.	L	L	X	X
Denver, Colo.	L	L	X	X	Oklahoma City, Ok.	G ⁴	G ⁴	C	O
Detroit, Mich.	A	A	X	X	Philadelphia, Pa.	L	L	C	X
Dubuque, Iowa	G	G	X	X	Phoenix, Ariz.	S	S	P	O
Duluth, Minn.	G ⁴	G ⁴	P	X	Pittsburgh, Pa.	A	A	X	X
Durham, N. C.	A	A	C	O	Pontiac, Mich.	A	A	X	X
Elmira, N. Y.	G	X	X	X	Portland, Me.	S	S	C	H ⁵
Flint, Mich.	A	A	C	O	Portland, Ore.	S	S	X	X
Fort Worth, Texas	G	X	X	X	Providence, R. I.	G	G	X	H
Fresco, Calif.	S	S	C	O	Richmond, Va.	L ²	L ²	X	X
Grand Rapids, Mich.	A	A	X	X	Rockford, Ill.	A	A	C	H
Honolulu, H. I.	S	S	C	O	St. Louis, Mo.	L	X	C	X

Table B1 (contd.)

	PVC Plastic DWV	ABS Plastic DWV	PE Plastic Water Pipe	CPVC Plastic Water Pipe		PVC Plastic DWV	ABS Plastic DWV	PE Plastic Water Pipe	CPVC Plastic Water Pipe
St. Petersburg, Fla	S	S	X	X	Tuscon, Ariz.	S	S	C	X
Salt Lake City, Utah	L ¹	L ¹	P	X	Tyler, Texas	X	X	X	H
San Francisco, Cal.	S	S	X	X	Washington, D. C.	A	A	X	H
Saratoga, Fla.	L ¹	L ¹	P	O	Wheeling, W. Va.	A	A	C	O
Shreveport, La.	A	A	C	O	Wichita, Kansas	S	S	P	O
Tacoma, Wash.	L ¹	L ¹	P	X	Wilmington, Del.	L	L	X	X
Tampa, Fla.	A ³	A ³	X	O	Winston-Salem, N. C.	A	A	C	X
Toledo, Ohio	A	A	X	X	Youngstown, Ohio	A	A	X	X

Table B2
State-of-the-Art Survey of Model Plumbing Codes and Similar
Documents for Limitations on Use of Thermoplastic Pipe
for Water Distribution and for DWV Applications

Code or Criteria ¹	DWV Piping		Water Distribution Piping	
	Above Ground	Below Ground	Cold	Hot
1. Model Plumbing Codes ²				
National (NPC) ASA A40.8 - 1955 (Under Revision)	N/A ³	N/A ³	N/A ³	N/A ³
Basic (BPC) BOCA 1970 Supplement 1973	ABS, PVC ⁴	Schedule 40 ⁴ plastic	Plastic ⁴ Cold Water	CPVC ⁴
Uniform (UPC) IAPMO 1973	ABS, PVC ⁵ (2 stories)	ABS, PVC ⁵ (2 stories)	N/A ⁵	N/A ⁵
National Standard (NSPC) PHCC 1971 ASPE - PHCC 1973A	ABS, PVC ⁶ Schedule 40	ABS, PVC ⁶ Schedule 40	Approved ⁶ plastic	Approved ⁶ plastic
Southern Standard (SSPC) SBCC 1971 Revisions 1974	ABS, PVC ⁷ (60' height)	ABS, PVC ⁷ (60' height)	CPVC ⁷	CPVC ⁷
Canadian (CPC) NRCC 1970 Revisions 1973	ABS, PVC ⁸ (36' height)	ABS, PVC ⁸ (36' height)	CPVC ⁸	CPVC ⁸

Table B2 (contd.)

Code or Criteria ¹	DWV Piping		Water Distribution Piping	
	Above Ground	Below Ground	Cold	Hot
2. HUD Minimum Property Standards ⁹				
One and Two Family Housing	ABS, PVC	ABS, PVC	CPVC	CPVC
Multi-Family Housing	ABS, PVC (6 stories)	ABS, PVC	N/A	N/A
Rehabilitation of Housing	ABS, PVC	ABS, PVC	CPVC	CPVC
3. Operation BREAKTHROUGH Guide Criteria ¹⁰				
Single Family Housing	ABS, PVC (3 stories)	ABS, PVC	CPVC	CPVC
Multi-Family Housing	ABS, PVC (3 stories)	ABS, PVC	CPVC	CPVC

¹ All major codes have a provision for "approval" of alternate materials which states, for example, that "Provisions of this code are not intended to prevent the use of any material, device, . . . provided such alternate has been approved by the Administrative Authority . . ." Quite often such approvals are at best difficult to obtain.

² See section 8.1 for addresses of model-code sponsors.

³ Use of plastic pipe is **not authorized**, N/A

⁴ From paragraph P-405.13: The water distribution system shall be . . . or . . . CPVC hot and cold water plastic pipe or plastic cold water pipe.

From paragraph P-405.21: Above Ground Piping Within Buildings—Soil and Waste piping . . . shall be . . . or . . . ABS plastic or PVC plastic pipe.

From paragraph P-405.22: Underground Building Drains—All underground building drains shall be . . . or Schedule 40 plastic pipe.

From paragraph P-405.31: Above Ground Venting—Vent piping installed above ground shall be . . . or . . . ABS plastic pipe or PVC plastic pipe.

From paragraph P-405.32: Underground Venting—Underground vent piping shall be of . . . (or) . . . Schedule 40 plastic pipe or . . .

Each of the above paragraphs have the additional requirement that: "All plastic pipe shall be marked with the appropriate identification of a quality control agency recognized in duly authenticated reports from Building Officials and Code Administrators International.

⁵ Section 401(a): Drainage pipe shall be . . . ABS, PVC or . . . except ABS or PVC installations limited to residential construction not more than two stories in height.

Section 401(b) Drainage fittings shall be . . . ABS, PVC or . . . having a smooth interior waterway of the same diameter as the piping served and all such fittings shall conform to the type of pipe used.

Sections 502 and 503: Vent pipe and . . . vent fittings . . . shall be . . . ABS, PVC or other approved material.

Installation standards IS-5-71 and IS-9-71 identify requirements that are in addition to the following:

Section 316(a)(6) Plastic pipe shall be maintained in the straight alignment.

Section 316(b)(7) Plastic pipe shall be supported at not to exceed four (4) feet.

Section 803(f) Joints in ABS and PVC pipe shall be made as provided in 802(m).

⁶ Section 11.1.1: Soil and waste piping above ground in buildings shall be . . . or . . . ABS or PVC Schedule 40 or heavier plastic pipe.

The same materials are permitted in the following uses:

Section 11.1.2: All underground building drains . . .

Section 12.1.1: Vent piping above ground in buildings . . .

Section 12.1.2: All underground vent piping . . .

Section 10.10.2: Water distribution pipe shall be . . . or approved plastic pipe. From section 3.1.3: A material shall be considered approved if it meets one or more of the standards cited in Table 3.1.3 . . . and in the case of plastic pipe, also the listed standard of the National Sanitation Foundation.

⁷ Section 506.7—Plastic Pipe and Fittings for Drain Wastes and Vent: For plumbing drainage, waste and vents both above and below ground, indirect wastes and storm drains, for buildings not exceeding (60) feet in height.

Installations shall conform to installation procedures of ASTM D2661-1973 for ABS or ASTM D2665-1973 for PVC, except where conditions of the SSPC are more stringent in which case they shall apply.

There shall be no co-mingling of the two materials in the same system except through proper adapters. In all cases approved solvent cement designated for the particular material shall be used.

From Table 505: For water distribution piping (above ground) Chlorinated poly(vinyl chloride) CPVC, ASTM D2846-1970 with NSF seal of approval.

Section 1212.1(a) Above Ground—Materials for water distribution piping and tubing shall be . . . or . . . chlorinated poly(vinyl chloride) (CPVC), all to be installed with the appropriate approved fittings.

⁸Section 7.2.5.8(3) Plastic pipe shall not exceed 36 feet in stack of vent height.

Section 7.2.5.8(4) Requirements for plastic piping in relation to fire safety shall conform to Sentence 3.1.7.7(2) and Article 9.10.9.25.

Section 3.1.7.7(2) Plastic drain, waste and vent pipe shall not be used in systems that pass through or are located in a required fire separation.

Section 9.10.9.25 Combustible drain, waste and vent piping shall not be used in a plumbing system within a building where part of the system is located within or passes through a fire separation, except that where drain, waste or vent piping penetrates through a vertical fire separation, the piping on one side of the separation may be combustible provided the combustible piping is not located in a vertical shaft or in a fire separation.

Section 7.2.5.9(1) CPVC hot and cold water pipe fittings and solvent cements shall conform to CSA B137.6-1971 "Chlorinated Poly(vinyl chloride) (CPVC) Plastic Piping for Hot and Cold Water Distribution Systems."

Section 7.2.5.9(2) CPVC pipe and fittings may not be used in a system where the design water temperature may exceed 180°F or if the design pressure may exceed 100 psi.

Section 7.2.5.8 Plastic pipe, fittings and solvent cement used inside a building, in a drainage or venting system shall conform to (a) CAS B151.1-1967 (ABS) and (b) CSA 181.2-1967 (PVC).

⁹The limitations on the use of PVC and ABS are stated in "Use of Materials Bulletins" UM-53a and UM-5-respectively. The use is limited to low structures so that for multi-family structures the height may not exceed six stories, but when used for horizontal branches it may be used for any structure.

Limitation on use of CPVC for water distribution is stated in "Use of Materials Bulletin" UM-61. It may be used in the new construction of single and double family units. It may

also be used in rehabilitated structures not exceeding six stories in height.

¹⁰Use of Schedule 40 ABS or PVC DWV plastic pipe is limited by the following considerations:

- a. ABS not to be used in multi-family high rise.
- b. For sizes 2" or less neither ABS or PVC shall be used for drains that can receive hot water at temperatures in excess of 165°F.
- c. Any plastic pipe must satisfy Operation BREAK-THROUGH fire criteria.
- d. Adequate provision shall be made to accommodate thermal expansion.
- e. National Sanitation Foundation certification or equivalent is required.
- f. Design and installation techniques shall be in accordance with generally accepted standards and industry recommendations.
- g. Pipe and fittings shall be appropriately marked to show NSF approval, applicable standards and manufacturer's name.
- h. All pipe, fittings, transition fittings, cement, hangers, and supports, etc. shall meet applicable generally accepted engineering practice.
- i. Acoustic control shall be provided in accordance with generally accepted engineering practice.

Schedule 30 has certain additional limitations:

- a. Not to be used for horizontal drains except water closet branches.
- b. Wall thickness must be at least 0.125 in. in the 3-inch size, 0.138 in. in the 4-inch size and 0.162 in the 6-inch size.
- c. Rationale and supporting data shall be provided for proposed applications in specific housing systems.

For use below ground, schedule 40 ABS or PVC plastic pipe is limited as follows:

- a. Detailed engineering analysis of soil pressures and supporting strength required, for as-installed condition.
- b. Requirements listed for above-ground use of Schedule 40 plastic pipe at (e), (f), (g) and (h) apply also to below-ground use.

Schedule 40 CPVC may be used above ground for water distribution with the following limitations:

- a. Limited to systems with storage-type water heater in living unit, thermostatted to limit water temperatures to 165°F or less; or
- b. to systems with non-recirculating central water heater thermostatted to limit water temperatures to 165°F or less; to branch piping only in systems with recirculating central water heater thermostatted to limit water temperatures to 165°F or less and with at least 12 inches of metal connector pipe at riser; or
- c. to systems with recirculating central water heater thermostatted and provided with automatic fail-safe shutoff valving to prevent water temperature rising above 140°F at any point in the water distribution system.
- d. Waterhammer protection required (either by limiting design velocities to 5 ft/sec, by the use of slow-closing valves, or by the use of air chambers or shock arrestors designed to limit overpressure to 150 psi or less). Maximum static pressure must be limited to 70 psi.

- e. NSF certification for use with potable water required.
- f. Adequate provision shall be made to accommodate thermal expansion and contraction.
- g. Design and installation techniques shall be in accordance with generally accepted standards and industry recommendations.
- h. Pipe and fittings shall be appropriately marked to show NSF approval, applicable standards, and manufacturer's name.
- i. All pipe, fittings, transition fittings, cements, hangers, supports, etc., shall meet applicable generally accepted standards.
- j. Rationale and supporting data shall be provided for proposed applications in specific housing systems.

APPENDIX C: RESULTS OF SURVEYS OF PLASTIC PIPE USERS

Survey of Military Users

Representatives from 24 major Army installations (Table C1)—16 percent of the approximately 150 large CONUS Army posts—were surveyed. Of the 26 individuals contacted, 12 completed the survey questionnaire. Their responses are summarized on the sample questionnaire shown in Figure C1.

Table C1
Army Installations Represented in User Survey

Fort Belvoir, VA	Fort Leonard Wood, MO
Fort Benjamin Harrison, IN	Fort Lewis, WA
Fort Benning, GA	Fort McCoy, WI
Fort Bliss, TX	Fort McPherson, GA
Fort Bragg, NC	Fort Meade, MD
Fort Drum, NY	Fort Monroe, VA
Fort Eustis, VA	Fort Richardson, AK
Fort Gordon, GA	Fort Riley, KS
Fort Hood, TX	Fort Sam Houston, TX
Fort Jackson, SC	Fort Sill, OK
Fort Knox, KY	Fort Steward, GA
Fort Lee, VA	Hunter Army Air Field, GA

In verbal discussions, only two indicated plastic pipe was not used at their facilities. About half indicated knowledge of problems with plastic pipe. The kinds of problems cited were essentially those given in the written responses to question 9.

The responses are believed to represent the extent of use of plastic pipe by Army facilities, the kinds of plastic pipe being used, its typical uses, and the problems encountered.

Survey of Civilian Users

Eight Engineering and architectural firms, contractors, and rural water distribution cooperatives were surveyed. Since some of the firms elected not to be identified by name, they are identified generically only. The following paragraphs summarize the comments received from each respondent.

User 1, an engineering firm, has more than 13 years of experience in designing and installing plastic pipe for water distribution, sewer, and DWV systems. They do not install plastic pipe in interior plumbing. Pipe used is 2 to 12 in. (51 to 306 mm) diameter PVC. Solvent welding is used only for DWV. Early uses of advent welded joints for water and sewer lines caused joint pull-out problems, so rubber ring joints are now used exclusively for water and sewer lines. Their experience has been good; no failures of joints have occurred in the past few years. No crushing of buried pipe has occurred. Estimated savings to customers range up to about 50 percent, depending on the size of the system. Their installations include more than 1000 mi (1600 km) of lines, including several hundred thousand joints in hilly rural and small municipal areas. Many common soil and stone types are prevalent in the areas of installation. Installation work has been done in all kinds of weather with no problems.

User 2, a plumbing and heating contractor, installs solvent-welded DWV systems primarily for residences. They use PVC almost exclusively and have found it easy to work with. They have had no problems in about 5 years of use.

User 3, another engineering firm, designs installations of DWV and electrical conduit of plastic pipe. They will not (by preference only) specify plastic pipe for use under concrete slab floors. They have had no problems over the past several years with solvent-cemented joints; before that, some joints caused trouble. This firm has found that plastic pipe requires closer spacing of hangers or supports (not more than 4 ft [1.2 m] apart), resulting in additional cost for these hangers.

PLASTIC PIPE USE SURVEY QUESTIONNAIRE

This survey is designed to obtain information about the use of plastic pipe. You are requested to give as complete and as frank answers as possible. The data you provide will be included in a report in a statistical manner and will not be identified to you or your organization.

1. Has plastic pipe been used at your facility? Yes 11 No 1

2. Circle the uses that have been made of plastic pipe at your facility.
 - a. water mains - 0
 - b. branch water lines - 6
 - c. interior cold water pipes - 3
 - d. interior hot water pipes - 0
 - e. drain, waste and vent pipes - 8
 - f. sewer lines - 3
 - g. gas distribution (LP or natural) - 2
 - h. irrigation (sprinkler) systems - 6
 - i. electrical conduit - 5
 - j. other (please specify) CO₂ lines to meters; exterior condensate return

3. Approximately how many feet of plastic pipe do you estimate has been used by your organization?
 - a. water mains 0
 - b. branch water lines 200-26,000 ft.
 - c. interior cold water pipes 1,000-2,000 ft.
 - d. interior hot water pipes 0
 - e. drain, waste and vent pipes 200-500 ft.
 - f. sewer lines 600-26,000 ft.
 - g. gas distribution (LP or natural) 10,000 ft.
 - h. irrigation (sprinkler) systems 5,000-10,000 ft.
 - i. electrical conduit 10,000 ft.
 - j. Other 400 ft.

4. Identify, if possible, the type of pipe used for each of the applications: PVC, CPVC, PE, ABS, Other.
 - a. water mains —
 - b. branch water lines PVC-5; PE-1
 - c. Interior cold water pipes PVC-2

**Written responses are in italics after each question.*

Figure C1. Summary of written responses.

- d. Interior hot water pipes _____
- e. drain, waste and vent pipes PVC-6; ABS-1
- f. sewer lines PVC-2; ABS-1
- g. gas distribution (LP or natural) _____
- h. irrigation (sprinkler systems) PVC-6; PE-1
- i. electrical conduit PVC-2
- j. Other PVC-2
5. What was the method of joining pipe used? *X* solvent (cement), *Y* threaded fittings, *Z* mechanical (clamps), or *U* other (please specify).
- a. water mains _____
- b. branch water lines x-4; y-1; 0-ring
- c. interior cold water pipes x-3
- d. interior hot water pipes _____
- e. drain, waste and vent pipe x-5; y-1
- f. sewer lines x-2; U (0-ring)-1
- g. gas distribution (LP or natural) x-1
- h. irrigation (sprinkler) systems x-5; y-1; z-1; U (Bell & Spigot)-2
- i. electrical conduit x-2; y-1
- j. Other 0-Ring
6. What building code or other specification was used as a guide allowing installation of plastic pipe?
- NSPC 1, SSPC _____, BOCA _____, UPC _____, CE Guide Specification 6,
Other (please specify) _____ *Manufacturer's specifications (2)*
7. Were tests conducted on the completed installation of plastic pipe? Yes 9
No 2 If so, what kind of test was performed? Please describe: _____
Standard pressure tests - (9)
8. How long has plastic pipe been in service at your facility? 1 1/2 yrs, 4 yrs, 6 yrs, 5 yrs, 3 yrs
9. Have there been any problems with the plastic pipe? Yes 4 No 5 If so, please describe:
Most problems are directly associated with improper assembly-3; thrust blocks not adequate-1

Figure C1 (Cont'd)

10. If problems have been experienced with plastic pipe, which of the following best describes the problem (check as many as required)?

- 4 Leaky joints
- 2 Broken pipe (cause heavy machinery crossing)
- Dimensional change in pipe
- Insufficient support
- 1 Improper backfilling, etc.
- 3 Improper installation due to untrained workers
- Inadequate inspector
- 1 Plastic pipe material was not good for the job

11. Do you have any knowledge of the use of power cleaners to clean out or unplug plastic sewer pipe? If so, describe any problems encountered.

No knowledge (1)

Use high velocity sewer cleaner (1200 psi at nozzle); no problems (1)

None or No (3)

12. Do you have personal likes or dislikes regarding plastic pipe? Please explain:

Like (1)

Dislike (0)

Need Guide Specifications (2)

Name: _____

Organization: _____

Address: _____

Telephone: _____

Figure C1 (Cont'd)

User 4, another engineering firm, has been designing plastic pipe water distribution and sewer systems for the past 8 years. Most of their systems are for subdivisions. Rubber ring joints are used; solvent welded joints are not used due to previous pull-out problems. They have had very few problems—probably less than they had with cast iron or cement asbestos systems. They believe plastic pipe offers significant benefits. They always specify ASTM- and NSF-approved pipe. They pressure-test systems the same way cast iron is tested, i.e., about 1.5 times the working pressure. Typical burial depth is 4 to 5 ft (1.2 to 1.5 m); no crushing problems have been experienced. They estimate that PVC water distribution lines cost about half as much (in place) as cast iron, with the cost of cement asbestos falling between those of plastic and cast iron. Low-temperature installations have been done with no problems. They do not approve of interior use of plastic pipe for plumbing, but stated that this opinion was not based on experience.

User 5 is a rural water cooperative which has a system that covers about 50 line miles (80 km) in south central Indiana. The system of 4 to 10 in. (102 to 254 mm) PVC pipe was installed in 1967. The terrain in the area is hilly and has mostly rocky or gravelly soil. They have had no major problems of water loss at joints. Lines have occasionally been damaged by being dug into; no crushed lines have been experienced. They are happy with the performance of the plastic pipe. Its lower ini-

tial cost made creating a rural water district possible; costs of other types of pipe would have been prohibitive.

User 6, a water company, has a system of about the same size and type as user 5's. Located in southeastern Kentucky, it covers about 75 line miles (130 km). Their experience has been about the same as user 5's. Their water system lines have been in use for 15 years and are performing well.

User 7, an engineering and architectural firm, indicated that the use of plastic pipe in the southwestern United States is outstanding from a corrosion-resistance standpoint. The soil chemicals present rapidly deteriorate steel or iron pipe unless cathodic protection is provided. They did not specify any direct design or installation experience.

User 8 is a utility company which used some plastic pipe for gas distribution a few years ago but has since abandoned its use due to leaks caused by gophers and other rodents.

The results of the survey generally indicate that plastic pipe is acceptable to engineers, contractors, and systems operators. Present pipe and installation techniques allow construction and use in water distribution and sewer systems, DWV systems, irrigation, and various other uses. Significant savings in initial material and labor costs and reduced maintenance costs result from the use of plastic pipe.

APPENDIX D: GUIDE SPECIFICATIONS POTENTIALLY AFFECTED BY THIS STUDY

This appendix lists the guide specifications which may be affected if plastic pipe is authorized for use in military construction and rehabilitation. Table D1 lists the potentially impacted military construction guide

specifications, Table D2 the military family housing guide specification, and Table D3 the military emergency construction guide specifications.

Table D1
Military Construction Guide Specifications

Number	Title	Remarks
CE-300.01	Plumbing, General Purpose	Spec calls out use of plastic pipe for certain DWV systems. Para. 16 would include water service pipe of plastics in accordance with model codes.
CE-300.02	Plumbing, Hospital	Plastic pipe mentioned in para. 3.4.1, 3.6.1, and 3.7 DWV. PVC or CPVC could be used in 3.6, and PVC or ABS could be specified in 26 and 32.4 for compressed air and vacuum piping.
CE-300.05	Gas Fitting	Interior gas lines and fittings restricted to metallic materials.
CE-301.37	Air Supply and Distribution System	References CE-300.01.
CE-501	Water Lines	High potential savings area by having plastic pipe specified and used as it is in civilian sector. Paragraphs potentially impacted are 3.1, 3.2, and 3.3 for materials; 4.1.9 (specify PVC and PE pipe); 4.2 series specify joining methods; 4.3 series, fitting and specials; 4.4.3, couplings for plastic pipe; 4.5.6, valves for plastic pipe.
CE-600.01	Sewers, Sanitary Gravity	Could show appropriate use of PVC, ABS, or PE in a subparagraph of 3, Materials.
CE-805.02	Subdrainage Systems	Does not mention plastic pipe. Could use PE in subparagraph of 2, Pipe for Subdrains.
CE-900	Gas Distribution Systems	Specifies PVC and PE as allowed materials.
CE-02503	Foundation Drainage System	Specifies use of plastic pipe
CE-15049	Vacuum Piping System	No mention of piping of any type. PVC could be used.
CE-15406	Oxygen Piping System	Specifies copper type K; probably should not specify plastic pipe or tubing due to specific use of transported gas.
CE-15408	Nitrous Oxide Piping System	Specifies copper type K; probably should not specify plastic pipe or tubing.

Table D2
Military Family Housing Guide Specifications
(DOD 4270.21)

Number	Title	Remarks
2.5	Foundation Drains	Para. 3 specifies PVC and ABS
2.14	Storm Drainage System	No mention of plastic pipe; could use PVC, ABS, or PE.
2.15	Lawn Sprinkler System	Specifies Use of ABS, PVC, and CPVC pipe and fittings.
15.1a	Plumbing	Could use PVC, CPVC, and PB.
15.8	Gas Fitting, Interior	Does not call out use of plastic pipe.
15.9	Gas Distribution Systems, Exterior	Specifies only steel or cast iron; could use PVC or PE.
15.10	Water Distribution System	Specifies steel pipe; could use PVC.
15.13	Sanitary Sewerage System	Allows use of PVC and ABS.

Table D3
Military Emergency Construction Guide Specifications

Number	Title	Remarks
CE-E-44-1 (Int.)	Plumbing	Could use PVC.
CE-E-44-2	Gas Fitting	Specifies steel or iron pipe.
CE-E-65-1	Storm Drainage System	No mention of plastic pipe; could use PVC or PE.
CE-E-65-2	Subdrainage System	No mention of plastic pipe; could use PVC, ABS, or PE.
CE-E-72	Irrigation System	No mention of plastic pipe; could use PVC or PE.
CE-E-73-1	Water Supply Lines and Distribution System	Allows use of PVC schedule 120 only. Could allow use of lower strength pipe in many instances.
CE-E-73-2	Sanitary Sewers	No mention of plastic pipe; could use ABS, PVC, or PE.
CE-E-73-7	Gas Distribution System	Steel or wrought-iron pipe specified; PE or PVC could be used.

Picatinny Arsenal
ATTN: SMUPA-VP3

US Army, Europe
ATTN: AEAEN

Director of Facilities Engineering
APO New York, NY 09827
APO Seattle, WA 98749

DARCOM STIT-EUR
APO New York 09710

USA Liaison Detachment
ATTN: Library
New York, NY 10007

US Military Academy
ATTN: Dept of Mechanics
ATTN: Library

Chief of Engineers
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ATTN: DAEN-MCE-D
ATTN: DAEN-FEU
ATTN: DAEN-FEB
ATTN: DAEN-FEZ-N
ATTN: DAEN-MCZ-S (2)
ATTN: DAEN-RDL
ATTN: DAEN-MCE-U (10)
ATTN: DAEN-PMS (12)
for forwarding to
National Defense Headquarters
Director General of Construction
Ottawa, Ontario K1A0K2
Canada

Canadian Forces Liaison Officer (4)
U.S. Army Mobility Equipment
Research and Development Command
Ft Belvoir, VA 22060

Div of Bldg Research
National Research Council
Montreal Road
Ottawa, Ontario, K1A0R6

Airports and Const. Services Dir.
Technical Information Reference
Centre
KAOL, Transport Canada Building
Place de Ville, Ottawa, Ontario
Canada, K1A 0N8

British Liaison Officer (5)
U.S. Army Mobility Equipment
Research and Development Center
Ft Belvoir, VA 22060

Ft Belvoir, VA 22060
ATTN: ATSE-TD-TL (2)
ATTN: Learning Resources Center
ATTN: Kingman Bldg, Library

US Army Foreign Science &
Tech Center
ATTN: Charlottesville, VA 22901
ATTN: Far East Office

Ft Monroe, VA 23651
ATTN: ATEN
ATTN: ATEN-FE-BG (2)

Ft McPherson, GA 30330
ATTN: AFEN-FEB

Ft Lee, VA 23801
ATTN: DRXMC-D (2)

USA-CRREL

USA-WES
ATTN: Concrete Lab
ATTN: Soils & Pavements Lab
ATTN: Library

6th US Army
ATTN: AFKC-LG-E

1 Corps (ROK/US) Group
ATTN: EACI-EN
APO San Francisco 96358

US Army Engineer District
New York
ATTN: Chief, Design Br
Buffalo
ATTN: Library
Saudi Arabia
ATTN: Library

CERL DISTRIBUTION

US Army Engineer District
Pittsburgh
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ATTN: Chief, Engr Div

Philadelphia
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Norfolk
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Huntington
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ATTN: Chief, Engr Div

Wilmington
ATTN: Chief, SAWCO-C

Charleston
ATTN: Chief, Engr Div

Savannah
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ATTN: Chief, SASAS-L

Jacksonville
ATTN: Library
ATTN: Const. Div

Mobile
ATTN: Library
ATTN: Chief, SAMEN-D
ATTN: Chief, SAMEN-F

Nashville
ATTN: Chief, ORNED-F

Memphis
ATTN: Chief, Const. Div
ATTN: Chief, LMED-D

Vicksburg
ATTN: Chief, Engr Div

Louisville
ATTN: Chief, Engr Div

Detroit
ATTN: Library
ATTN: Chief, NCEED-T

St. Paul
ATTN: Chief, ED-D
ATTN: Chief, ED-F

Chicago
ATTN: Chief, NCCCO-C
ATTN: Chief, NCCED-F

Rock Island
ATTN: Library
ATTN: Chief, Engr Div
ATTN: Chief, NCRED-F

St. Louis
ATTN: Library
ATTN: Chief, ED-D

Kansas City
ATTN: Library (2)
ATTN: Chief, Engr Div

Omaha
ATTN: Chief, Engr Div

New Orleans
ATTN: Library (2)
ATTN: Chief, LMNED-DG

Little Rock
ATTN: Chief, Engr Div

Fort Worth
ATTN: Library
ATTN: SWFED-D
ATTN: SWFED-F

Galveston
ATTN: Chief, SWGAS-L
ATTN: Chief, SWGCO-C
ATTN: Chief, SWGED-DC

Albuquerque
ATTN: Library
ATTN: Chief, Engr Div

Los Angeles
ATTN: Library
ATTN: Chief, SPLED-F

San Francisco
ATTN: Chief, Engr Div

Sacramento
ATTN: Chief, SPKED-D
ATTN: Chief, SPKCO-C

Far East
ATTN: Chief, Engr Div

Japan
ATTN: Library

Portland
ATTN: Library
ATTN: Chief, DB-6
ATTN: Chief, FM-1
ATTN: Chief, FM-2

Seattle
ATTN: Chief, NPSCO
ATTN: Chief, NPSEN-FM
ATTN: Chief, EN-DB-ST

MSC

US Army Engineer District
Walla Walla
ATTN: Library
ATTN: Chief, Engr Div

Alaska
ATTN: Library
ATTN: NPADE-R

US Army Engineer Division
Europe
ATTN: Technical Library

New England
ATTN: Library
ATTN: Laboratory
ATTN: Chief, NEDCD

North Atlantic
ATTN: Library
ATTN: Chief, NADEN

South Atlantic
ATTN: Library
ATTN: Laboratory
ATTN: Chief, SADEN-TC

Huntsville
ATTN: Library (2)
ATTN: Chief, HNDED-CS
ATTN: Chief, HNDED-SR

Lower Mississippi
ATTN: Library
ATTN: Chief, LMVED-G

Ohio River
ATTN: Laboratory
ATTN: Chief, Engr Div
ATTN: Library

North Central
ATTN: Library

Missouri River
ATTN: Library (2)
ATTN: Chief, MRDED-G
ATTN: Laboratory

Southwestern
ATTN: Library
ATTN: Laboratory
ATTN: Chief, SWDED-TG

South Pacific
ATTN: Laboratory

Pacific Ocean
ATTN: Chief, Engr Div
ATTN: FM&S Branch
ATTN: Chief, PODED-D

North Pacific
ATTN: Laboratory
ATTN: Chief, Engr Div

Facilities Engineer
FORSCOM
Ft Devens, MA 01433
Ft McPherson, GA 30330
Ft Sam Houston, TX 76234
Ft Carson, CO 80913
Ft Campbell, KY 42223
Ft Hood, TX 76544
Ft Lewis, WA 98433

TRADOC
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